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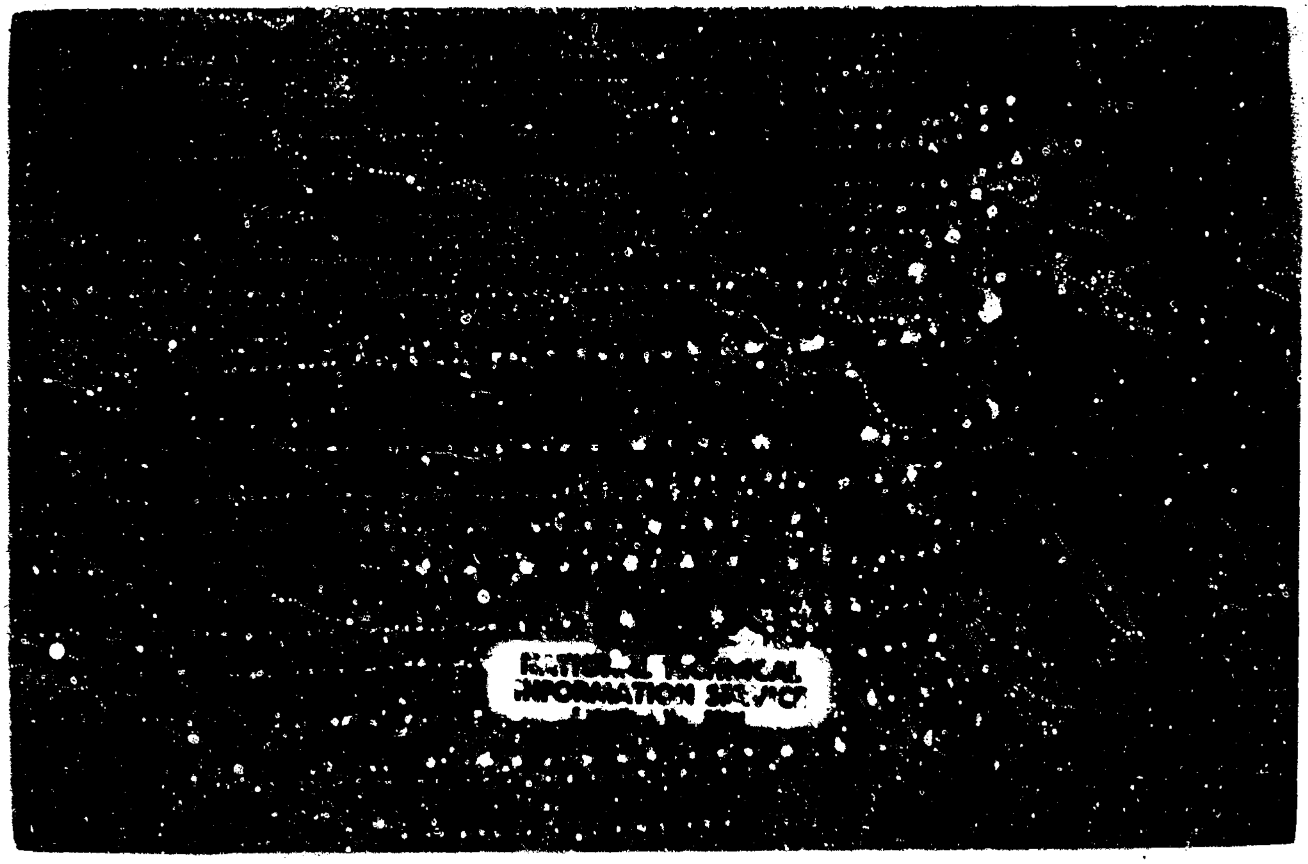

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13. ABSTRACT

Report describes a study of methods for surveillance of Ocean Dumping Operations in New York Bight. General requirements, system approaches and system specifics are discussed. Applicable candidate systems are described and are rated. Total cost of ownership is considered. The recommended system is described in the text and in hardware-procurement and installation specifications. Recommended system uses Loran A for position fixing, draft sensing for detecting occurrence of dump, and means for recording these and other important events. For maximum application flexibility, a dump detection subsystem is added to basic system. Basic system is called Loran-Events-Printer-System. When a more positive sensing of dump is added on the same vessel, total system is called Draft-Events-Loran-Printer-System. When dump sensing occurs on a towed barge or scow, equipment on the towed vessel is called Scow, Indicating Draft System. Basic system is contained in a single "black-box", requires little vessel preparation, and can be placed aboard a vessel upon short notice. No system configuration requires a connection between a towed dumper and the towing tug. The recommended system requires no major development effort. System concept involves the recording every 6 minutes of vessel position, the recording of important events, and the recording of draft sensing if desired. Provision is also made for recording other dump status signals. Indicators showing read-outs of the Loran lines-of-position are visible for use as a navigation aid.

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SYSTEM STUDY
FOR SURVEILLANCE OF
OCEAN DUMPING OPERATIONS

Prepared for

U.S. ARMY CORPS OF ENGINEERS
NEW YORK DISTRICT
NEW YORK

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SPERRY SYSTEMS MANAGEMENT DIVISION
Sperry Rand Corporation
Great Neck, N.Y. 11020

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ABSTRACT

This report describes a study of surveillance of Ocean Dumping Operations in the New York Bight. General requirements, system approaches and system specifics are discussed. Applicable candidate systems are described and are rated using customized evaluation and analysis techniques, including consideration of total cost of ownership. The "preferred" system thus defined is described in the text and in appended hardware procurement and installation specifications. The preferred system utilizes Loran A for position fixing, draft sensing for detecting the occurrence of dump, and means for recording these as well as important events. For maximum application flexibility, a dump detection subsystem is added to a basic system. The basic system is called "LEPS" (for Loran-Events-Printer-System). When a more positive sensing of dump is added on the same vessel, the total system is called "DELPS" (for Draft-Events-Loran-Printer-System). When the dump sensing occurs on a towed barge or scow, the equipment on the towed vessel is called "SIDS" (for Scow, Indicating Draft System). The basic system is contained in a single "black-box", requires minimal vessel preparation, and has the advantages of transportability in that it can be placed aboard a vessel upon short notice. No system configuration requires a connection between a towed dumper and the towing tug. Furthermore, the preferred system requires no major development effort. The system concept involves the recording every six minutes of vessel position as determined by automatic tracking Loran receivers, the recording of important events as they occur, and the recording of draft sensing if desired. Provision is also made for recording other dump status signals (like dump valve status, etc.). Indicators showing read-outs of the Loran lines-of-position are visible for use as a navigation aid, at the discretion of the captain.

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SECTION 1.0

INTRODUCTION AND SUMMARY

1.1 PURPOSE OF STUDY

The Army Corp. of Engineers has the responsibility to grant permission for the dumping of wastes in the ocean. These permits authorize the dumping of wastes in specific dump areas according to the nature of the waste material. Ocean dumping is believed to be occurring in locations other than the prescribed dump areas. The extent and type of the violations is not exactly known because of the present lack of a suitable monitoring system, but it is assumed that the violations are rarely attributable to safety considerations or emergency conditions. The convenience and comfort of the captain or crew are possible prime factors. Rough seas and generally bad weather are consequently likely conditions for early dumping. It is expected that faulty navigation occasionally may result in a dump in other than the licensed location.

For many reasons, including the potential severity of the impact of such practices on the environment, the New York District wishes to assure that the dumping of wastes is indeed taking place according to the provisions of the permits and applicable regulations, and accordingly has authorized a planning program to define a surveillance monitoring system.

The problem is stated as follows: Ocean dumping by licensed dump vessels is occurring in other than the assigned dump areas. Since this is a violation of dumping regulations (for whatever the cause), the New York District is confronted with the problem of limiting such violations by whatever legal means are available, such as imposing severe fines and revoking permits. It remains then to define a system which can provide the base for corrective actions.

On 22 March 1971 the New York District authorized the Sperry Systems Management Division, SSMD, to proceed with a planning program to accomplish the following:

- Examine the New York ocean dumping scenario,
- Determine system rating criteria,
- Determine system specifics,
- Review approaches and candidate systems,
- Examine performance characteristics,
- Examine comparative costs,
- Rate candidate systems
- Select and recommend a "preferred" system
- Prepare an implementation plan.

The results of the planning program conducted by SSMD are presented in this report.

1.2 GENERAL REQUIREMENTS AND SYSTEM APPROACHES

Since this was not purely a theoretic study to increase the scientific bank of knowledge, but rather was a program to define a system and develop a plan capable of being readily implemented, practicality was of prime importance. The system approach was to consider equipment to:

- Sense the occurrence of dump;
- Sense the location of the dump; and,
- Suitably record the data.

Factors contributing to the requirements and approaches are discussed in sections 2 and 3 of this report. Both real-time and post-occurrence reporting of the recorded data were considered. Also considered were the following desirable system features:

- Positive detection of dumping violations,
- Simple operating procedures,
- Minimal equipment,
- Reliable, proven equipment,
- All-weather operation,
- Common equipment for different types of vessels,
- Compatible with existing and future ocean disposal requirements,
- Simple maintenance,
- Easily made operational
- Tamperproof
- High legal effectivity
- High cost effectivity.

1.3 CANDIDATE SYSTEMS

A large number of candidate systems were considered, as described in section 4 of this report. Of the many candidates, the following were most attractive.

- to sense occurrence of dump;
  - Draft sensors,
  - Monitoring of Dump commands and actuators,
  - Monitoring of Dump valves, doors, etc., and
  - Events entered by captain at start and end of dump.
- to sense location of dump;
  - Omega,
  - Loran C,
  - Loran A,
  - Shore-based RDF, and,
  - Shore-based Radar,

- to record the data;
  - Magnetic tape,
  - Punched paper tape, and
  - Alpha-numbric printed paper tape.

1.4 SUMMARY OF RESULTS

The system rating criteria and evaluation procedure are presented in Section 5 of this report. Performance, Reliability, Maintainability and costs are discussed respectively in Sections 6, 7, 8, and 9. The various candidate systems are rated in Section 10. These considerations have led to the identification of a recommended "preferred" system which is described in Section 11 and forms the base for the implementation specifications of Appendices D, E, F, and G.

The recommendation for the Dump Monitoring System (DMS) is a basic system embodying loran for navigation and position fixing, an events unit for entering start and end of dump and other significant events, and a printer to provide a written record of dump-related activities. This basic system, called LEPS for Loran Events Printer System, would be augmented by positive dump sensing when appropriate. This approach is recommended as the result of a systematic consideration of many factors and, as discussed in the report, best satisfies all requirements. In operation, ship position is continuously recorded (every 6 minutes) by printing two lines of position from two on-board automatic-tracking loran receivers. Also, the two LOP's are presented to the captain for use, at his discretion, as a navigation aid. The captain presses a button on the events unit at the start of dump and another button to indicate the completion of dump. The events unit is also used to enter other significant events such as "passing Ambrose now", etc. The printer is a 21-channel paper tape alpha-numeric printer.

Appropriate fusing and loss-of-function alarms are provided. The equipment for the basic system LEPS is housed in a single equipment rack which can be table or deck mounted, requiring very little shipboard space. Only four electrical connections to the rack are required. Two for primary electric power, and two for r-f (one antenna and one ground). The simple installation and low weight packaging is a decided advantage of the LEPS, since it permits use of a "portability" concept for use aboard ships that only occasionally dump and do not justify the investment of a permanently installed system.

An additional feature of the recommended system, LEPS, is that it requires no equipment aboard a towed dump scow. Thus in an operation where any of numerous tugs may tow one or more scows to the dump area where the trip is frequently made, the LEPS, when not in use, could be kept at the scow-loading area and, using the LEPS portability feature, placed aboard the selected tug at the time the tug picks up the scow.

Furthermore, the fact that LEPS does provide two Loran LOPS for use by the captain as navigation aids (at his discretion) is another decided advantage.

The LEPS includes no equipment for sensing the occurrence of dump and, instead, relies upon the captain to enter the start of dump and end of dump via the events unit. This system has many attractive features but certain situations require a more positive dump detection. To accommodate these applications, a draft sensing sub-system would be added to the basic system. When contained on one vessel the LEPS plus

draft sensor is called "DELPS" (for Draft-Events-Printer-System). Examples of such installations are self-propelled dumpers (like Newtown Creek, sewer sludge dumper) or sophisticated barges with larger on-board crews and significant power generation capability (like Moran 108 barge used for National Lead's acid waste). When the application involves a barge or scow which has crew or power limitations, the towing tug would carry the basic LEPS and the barge would carry a Scow Indicating Draft System (called "SIDS").

1.5 CONCLUSION

The problem of monitoring sea-dump operations can be solved in a practical way by employing the recommended systems, DELPS or SIDS and LEPS. The recommended systems satisfy all requirements while representing low-cost approaches which are immediately applicable for the present dump sites and require no modification should the dump sites move offshore 100 or 150 miles. Furthermore, the recommended systems can be used in any area covered by LORAN (for practical purposes, all of continental USA), for the monitoring of ocean dumping of waste material.

SECTION 2.0

SYSTEM SPECIFICS

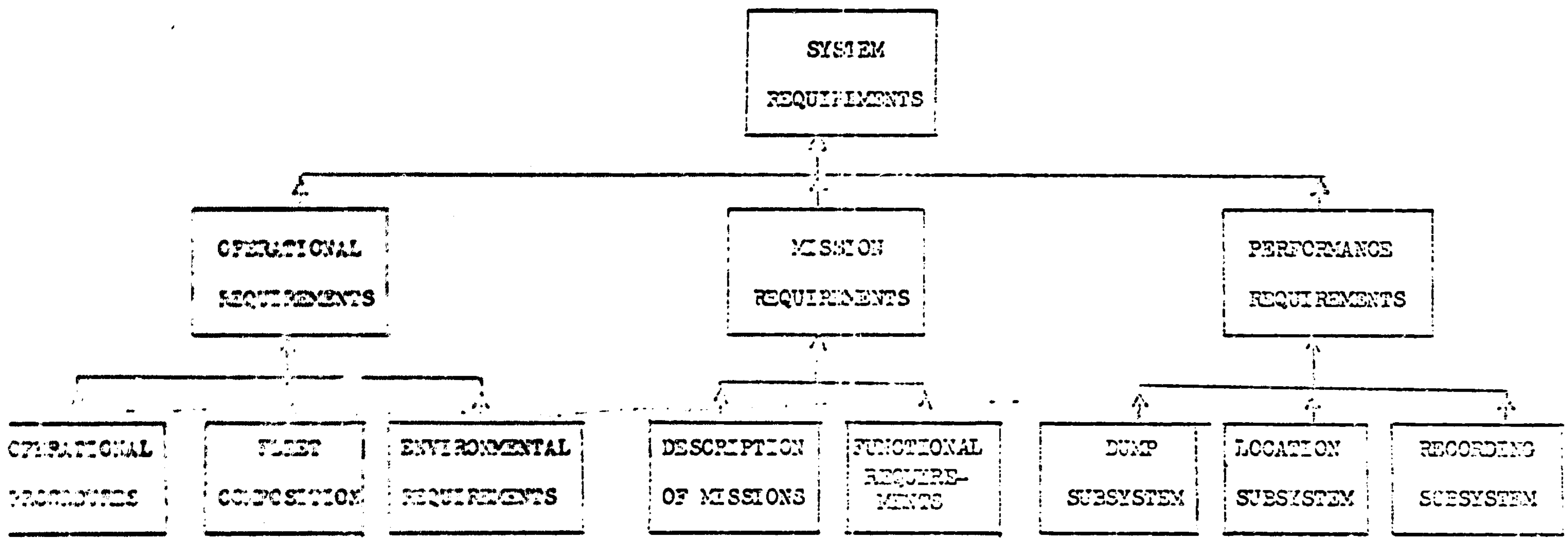
2.1 GENERAL

The synthesis and evaluation of candidate systems for the Dump Monitoring System requires a comprehensive understanding of present operational dumping practices and detailed information and characteristics of the dump vessels themselves including vessel berth locations, speed, range, dump control specifics (actuation mechanisms and control), and navigation and communication equipments. Additional factors to be considered include dump vessel traffic, type and composition of dump material, existing shore facilities which may be utilized for the DMS and vessel owner/captain cooperation. With the above information, system requirements including operational requirements, mission requirements and subsystem performance requirements can be formulated and utilized for evaluation of system approaches and rating of candidate systems. Figure 2-1 shows in diagrammatic form, the pertinent factors to be considered in establishing system requirements. These factors are discussed in this section.

2.2 OPERATIONAL REQUIREMENTS

2.2.1 Fleet Composition

The dump fleet is comprised of both self-propelled dump vessels and towed barges or scows operating from berths in Manhattan, Westchester, Long Island and New Jersey. For the most part, the same vessels are regularly involved in dumping and would logically have a DMS permanently installed. However, for use with vessels only occasionally involved with a dump, a portable system which can be quickly installed aboard would be



FACTORS ESTABLISHING SYSTEM REQUIREMENTS

FIGURE 2-1

desirable. Table 2-1 presents a summary of tugs and dumping vessels, by company, comprising the dump fleet to which the N.Y.D.C.E. issues permits for ocean dumping. During the study, these companies were contacted to obtain specific information concerning operating procedures, materials dumped, areas of operation, on-board equipments utilized and dumper characteristics, such as type of dump mechanisms utilized, draft changes from unloaded to loaded states, manual or automatic actuation of dump controls, and speed. Visits were made to several of the companies' loading docks and offices to obtain additional information and understanding of operational procedures and dump vessel characteristics. These included visits to Great Lakes Dredge and Dock Co., Moran Towing and Transportation Co., and Dept. of Water Resources, Bureau of Water Pollution. The remarks contained in Table 2-1 are derived from information obtained from those visits as well as telephone conversations with knowledgeable personnel of the companies. Pertinent information and data related to the present study of ocean dump monitoring systems are summarized below.

- Dump scows presently used for ocean dumping of dredge spoils are of several basic types employing different dump actuating mechanisms and configurations. Older and smaller scows generally contain 6 or 8 pockets, each of which contain double, gravity dump, bottom doors normally held closed by cables and a ratchet and pawl type mechanism. Release of the pawl for "dumping" is provided by hydraulic jacks operated by control valves

TABLE 2-1

SUMMARY OF TUGS AND DUMPING VESSELS COMPRISING DUMP FLEET

Company	Tugs	Dumpers	Remarks
..&S Modern Transportation Company	None	7 Barges including Raritan, Liquid Waste #1, Forrest	Carry mostly sewer sludge but at times caustic wastes to 100 mile dump site (with hinge type barge); use Moran & McAllister tugs
'llied Chemical orp.	None	Allied Chemical #5	Towed barge, carries acid waste to acid grounds, barge has 4 tanks, compressed air used to pump out liquid, one hr. per tank, manually operated at present (expect to use remote dump control next month.
merican Dredging ompany	Albany Troy Caven	#134, 135, 136, 137, 138, 139, 156, and 159	Carry dredge material, bottom dump barges used with hydraulic activation of doors; scowman operates dump controls, limited power aboard barge.
Dunbar & Sullivan redging Company	R. H. Goode	#118, 119	As above
Great Lakes Dredge nd Dock Co.	D. C. Lynn John Downs Feeley	#9, 10, 12, 13, 14, 40, 41, 42, 43, 61, 62, 80, 81, 90, 91, 92, 93, 94, and 95	Carry mostly dredge material. Bottom dump barges of hinge type or pocket type (6 to 8 pockets) with double doors hydraulically operated and controlled by scowman, tugs use radar for dump site location.
cAllister Brothers, nc.	Grace, Jane, Brian, A.J. David, Timothy Justine, G.M. Donal Dorothy, Eagles, Margaret, Nancy, and Muriel McAllister	WESTCO #1	Tugs contracted by other companies; WESTCO #1 sewer sludge vessel used by Westchester County sewer authority, has 2 pockets, pump out sewage
Moran Towing and Transportation Co.	Teresa, Cathleen, Patricia Michael, Eugene Harriet, Helen Margot, Anne, Ester, Carol, Cynthia, Nancy, Diana, Eugenia, Grace, Elizabeth, Joan, and Helen Moran	Moran #102 104 106 108 110	Tugs contracted by other companies; tow dredge spoils, cellar dirt, sewer sludge, and acid barges; 102, 103, 106, & 110 used for cellar dirt, 108 for acid wastes, sometimes dumpers taken to anchorage in Brooklyn and later hauled out to sea.

TABLE 2-1

SUMMARY OF TUGS AND DUMPING VESSELS COMPRISING DUMP FLEET

(Continued)

Company	Tugs	Dumpers	Remarks
Red Star Towing & Transport. Co.	Ocean Star, Port Jefferson, Ocean Prince, Red Star	None	Tugs contracted by other companies; all tugs have Loran for navigation aid for 100 mile dump site.
[illegible]ntonbush Fuel Transport. Service	None	Sparkling Waters	Carry caustic wastes (Dupont, American Cynamido, Chevron, Humble Companys); Dunbarge towed by Red Star Towing. Remotely operated dump control from tug; barge has 4-300,00[illegible] gallon tanks. No scowman on barge.
Standard Tank Cleaning Corp.	None	Susan Frank	Self propelled dump sewage vessel used by Nassau County; has 6 pockets with manually operated gate valves.
Standard Tank	None	#101, 103, 104	Generally carry dredge spoils; contracted by other companys, business primarily in marine construction.
[illegible]recamo Coastal & Harbor Towing Corp.	Francis, Barney, Jean, Kathleen, Boys, Marie J, James, Girls, Margaret, and Helen Turecamo	None	Provide towing service; tugs are diesel powered and have gyrocompass, radar & RDF equipment, no control on tugs to activate dump average tow speed is 7 knots.
[illegible]t. of Water Resources Bureau of Water Pollution		Coney Island, Bowery Bay, Tallmans Island, Owls Head and Newton Creek	Self propelled sewer sludge vessels; Owls head has 3 double tanks and sewage dumped by manually operated gate valves. Vessel contains radar and radio; speed out approx. 11 knots makes 38 mile round trip.
[illegible]ean Disposal Co.	None	Ocean Disposal #1	Carry sewer sludge, chemical waste; Dunbarge bottom drop dumper with 8 pockets; hydraulically operated plug valves which can be manually or remotely activated. Towing speed approx. 7 knots, 33 hour round trip to 100 mile dump site.

located within the scow bridge; the scowman manually controls operation of the valves for each pocket dump mechanism.

Several of the dump scows are of the hinge type configuration; the scow is comprised of a port and a starboard section which are hinged topside (fore and aft) about which the two sections rotate during dump operation. Large diameter hydraulic pistons located beneath the fore and aft hinges cause the two sections to bottom separate thus allowing the dredge spoils to gravity dump into the ocean. Dumping is actuated by a scowman activating hydraulic control valves. Dump time is on the order of several minutes.

On some barges the dumping is remotely activated and controlled from the towing vessel and a scowman need not be aboard the barge.

- Self-propelled dumping vessels are primarily used for sewer sludge disposal in New York and Long Island. Sewer sludge from New Jersey, however, is carried out by barges. The self-propelled vessels are outfitted with manually operated gate valves and the sludge is either gravity dumped or pumped out. The number of pockets on the self-propelled vessels varies from 2 to 6, depending on the vessel. Discharge time varies but is on the order of 15 minutes.

- Hazardous chemicals and caustic wastes are carried out to the long range dump site (approximately 100 miles) on scows towed by larger tugs using, in most cases, Loran A for navigation. The scows are unattended for the most part and dumping is performed by remote control from the tug. Dumping time ranges from 30 minutes to 1½ hours.
- Significant draft change from loaded to unloaded states is evident on both the self-propelled dumping vessels and towed barges. On the average a change in draft of 12 feet may be expected.
- Navigation equipments found on the majority of the tugs and self-propelled vessels include gyrocompass, radio direction finder and radar. Tugs used for the 100 mile dumps in addition have Loran A receivers.
- Power aboard the dump scows is minimal and only used during dump. Scowmen aboard the barge generally use a gas lantern for lighting their quarters. The self-propelled dump vessels and tugs, on the other hand, have both D.C. and A.C. power available for radio, radar and other equipments as well as general lighting.

2.2.2 Operational Procedures

Operational procedures utilized by licensed ocean dumping companies are similar but vary somewhat due to the waste material to be dumped, the type and capacity of dumper utilized and vessel berth location. In all cases, however, permits allowing ocean dumping

are to be issued by the NJDEP for a specified period of time, depending on job circumstance, and may vary from 1 day to as long as 1 year.

As previously indicated, the dumping fleet berths are located on Long Island, New Jersey coastal and river locations and along the East and Hudson Rivers of New York. Operating procedures while enroute to the dump sites depend on the berth location since navigable inland bays and rivers, due to heavy traffic, will necessitate a closer towing distance between barge and tug as well as slower vessel speeds. In addition, on some routes low bridges will require the tug or vessel captain to phone ahead to have the bridge opened upon his arrival at that point. For the return leg of the dump mission to inland water bays and rivers, the captain may have to schedule his dump mission and time his arrival so that the tide is outgoing to permit control of the barge/tug in the event speed must be seriously curtailed due to heavy traffic. Otherwise the barge may become uncontrolled due to tides and currents.

Present operational procedure necessitates the vessel captain enroute to the dump site to communicate to the harbor supervisor when in the vicinity of New York Harbor. Dumping is generally performed on the move; the permit, however, usually spells out the dump method to be used. Upon reaching the dump site, the captain initiates commencement of dumping to the scowman by tug whistle.

Weather conditions sometimes prohibit dumping vessels from going

out to the dump sites. This may occur an average of 8 to 10 times during the year. With sewer sludge, large storage tanks, located at the sewer plant, are typically used for storage until the weather permits dumping operations to resume.

2.2.3 Environmental Requirements

Ocean dumping operations are performed 24 hours per day, 7 days per week throughout the year except for severe weather conditions which may jeopardize crew safety or result in vessel/dumper loss or damage. In the New York offshore area, severe weather conditions which prohibit dumping include hurricanes, severe blizzards or strong Northeasterly winds and gales. Personnel of several companies have indicated dumping is curtailed on the average between 8 to 10 days per year. Dumping operations, therefore, may be expected to be performed over a gamut of weather environments including fog, drizzle, snowstorms, ice storms, thunderstorms as well as in fair weather with corresponding conditions of temperatures, humidity, sea states and winds.

These weather environments may be expected to influence the operational performance of equipments (depending on their operating frequencies) and consequently become significant in evaluating system approaches and in rating promising candidate systems. Appendix B, Figure B-1 shows the range degradation of an X-band, pulse radar for various precipitation rates caused by back-scattering and attenuation in

rain. Degradation range due to fog is shown in Figure B-2. It is apparent that a system candidate utilizing radar will have a range limitation significantly affected by weather environments. Also shown in Appendix B is average normal and extreme weather conditions and meteorological data, compiled for 1970 by the U. S. Department of Commerce Environmental Data Service for the New York area, and statistical data from the Washington, D. C. area (which has comparable weather conditions to New York) indicating the number of hours during the year a given precipitation rate may be expected. The data will provide insight to the number of days during the year various forms of precipitation occur as well as thunderstorm activity, wind speeds and direction, and humidity conditions.

System candidates utilizing either low or high frequency transmission signals are also influenced by certain weather phenomena. Radio signals are propagated either along the surface of the earth (so-called ground wave) or reflected from the ionosphere (skywave) depending on the transmission frequency. Up to about 3 MHz, ground wave transmission predominates, whereas skywave propagation occurs between 3 and 30 MHz. In the latter case, the transmission path is unpredictable and consequently this propagation mode is of little value in navigational systems. Even with ground wave transmission, some skywave propagation takes place and special treatment sometimes is required to discriminate each signal. Ground wave transmission is affected by atmospheric noise and is observed to be worse at night, particularly at higher operating frequencies.

Also presented in Appendix B is atmospheric noise intensity as a function of frequency measured at Scituate, Massachusetts over a period of several years. At 1 MHz, the atmospheric night time noise is shown to be 500 times greater than the noise occurring during the day. Increasing the receiving antenna area does not help the situation since the increased area simply picks up more atmospheric noise. A further characteristic of ground wave transmission is the variation of propagation velocity which results from changes in conductivity and dielectric constant over the earth surface. Although this variation is small, corrections are necessary to assure accurate fixes, particularly at long ranges.

Above 30 MHz, transmission of signals is limited by line-of-sight (LOS). Ignoring multipath problems, the transmission path is highly predictable in the 100 MHz to 3 GHz frequency band and is unaffected by precipitation, atmospherics and time of day or season. Line-of-sight systems, however, are subject to horizon limits and the maximum useable range one might expect is given by the expression:

(2-1) $$R = 1.2\sqrt{h_T} + 1.2\sqrt{h_R}$$ where

R = range in n.m.

h_T = height of transmitting antenna in feet

h_R = height of receiving antenna in feet

Another aspect of the weather environment which has significance for the dump monitoring system results from the use of dump

detection sensors incorporated on the barge/vessel dump mechanisms. Ice and snow exposure at times prohibits normal operation of hydraulic actuated dump mechanisms and the scowman is often required to chip off the ice before the dump can be made. Installation of sensors at these locations are susceptible to damage during this freeing operation and, therefore, careful attention must be given to sensor installation location and case structure. It is apparent, too, that the sensor design should not itself employ a mechanism which may freeze under the same ice/snow exposure and, therefore, sealed electromagnetic type switches and latches are recommended. The dump detection sensors, as well as the other dump monitoring equipments, will be exposed to severe salt water and dump waste environments which necessitates careful selection of equipments and components capable of surviving under these service conditions.

2.3 MISSION REQUIREMENTS

2.3.1 Description of Missions

2.3.1.1 Dump Sites

Present ocean dumping operations in the New York Bight are regulated by the N.Y. District Corps of Engineers which issue permits for dumping at specific ocean locations, depending upon the material to be dumped. Within the N.Y. Bight, five dumping sites are utilized:

- Acid Waste Dumping Ground
- Sewer Sludge Dumping Ground
- Cellar Dirt Dump Ground
- Mud and One Man Stone Dumping Ground
- Wreck Dumping Ground

In addition to the above, a Hazardous Material Dumping Ground is provided for the dumping of caustic wastes and other chemicals considered hazardous if dumped near shore. The location of these dump grounds relative to Ambrose Light is given in Table 2-2.

TABLE 2-2 LOCATION OF DUMP SITES

DUMP GROUND	TRUE BEARING FROM AMBROSE LIGHT	DISTANCE FROM AMBROSE LIGHT (NM)
ACID - SUMMER	135°	10.7
ACID - WINTER	145°	9.2
SEWER SLUDGE	124° 30'	4.5 (10.0 NM TO POINT OF NEAREST LAND)
CELLAR DIRT	170°	4.7
MUD AND CHE [illegible] STONE	190°	4.0
WRECK	163° 30'	14.3
HAZARDOUS MATERIAL	--	Approx. 100NM

2.3.1.2 Time and Range of Missions

Since loading piers and docks are located at various points in New York, New Jersey and Long Island, the range to present dump sites from those locations varies. For the purpose of this study, an average range of 10 n.m. will be assumed for the near shore dump sites and 100 n.m. for the hazardous waste dump ground. The 100 n.m. range would also be applicable if dump sites are extended out to the edge of the continental shelf.

Total mission time, including dump time, varies and depends on vessel berth location, dump material carried, vessel

type and characteristics, traffic, and weather conditions. For the nearby dump sites, total mission time may vary between 5 to 8 hours whereas the long range dump mission is on the order of 40 hours. Generally the return trip time is somewhat less than the outbound trip, possibly due to the change in vessel draft or ocean currents.

At-sea density of dump vessels is important in formulating system approaches and in rating of candidate systems since it may preclude use of an otherwise acceptable and possibly high rated candidate system. Although the dump fleet is comprised of approximately 50 dumping vessels (excluding tugs), it is likely that only 15 are in service at any one time, and maybe 30 in any one day.

2.3.1.3 Presently Used Methods of Locating Dump Sites

The dump vessels leaving N.Y. Harbor and New Jersey navigate along either Ambrose or Sandy Hook channels to the near shore dumping grounds. The captain generally utilizes dead reckoning navigation (gyrocompass, tachometer and clock) to reach the dump sites and then takes several radar or radio direction finder fixes to accurately locate himself relative to the site. On the long range dump missions, Loran is utilized as a navigation aid to and from the dump site. For this mission a N.Y.D.C.E. inspector usually boards the dump vessel; it is required that the N.Y.D.C.E. be notified at least 48 hours in advance of the departure time for the long range dump mission.

2.3.2 System Functional Requirements

The primary objectives of the Dump Monitoring System are twofold:

1) The determent of ocean dumping in other than authorized dump locations, and
2) The successful identification of dumping violators with sufficient proof to institute legal action.

To accomplish the above objectives, the system should provide, as a minimum, the following functions:

1. Detection of Dump Occurrence
2. Vessel Location at the Time of Dump
3. Data Acquisition and Storage

These functional requirements are not to be considered as a firm requirement imposed on the DMS but are proscribed to indicate the general intent of the system objective. If, for example, a system approach continually monitored vessel location and time during the entire mission and conclusively showed that the dump vessel went to the dump site, it is reasonable to assume that the vessel did actually dump at the site since there would be no significant advantage for the captain to dump early. While the legal effectiveness of this approach is questionable, it most assuredly would deter illegal dumping since suspected violators would be given warning of license revocation if the illegal practice continued. Similarly, if a system approach utilized dump detection sensors on buoys moored

at the dump site and the dump detected signal recorded, along with vessel identification, it is reasonable to assume that the captain did not dump prematurely since, again, no significant advantage is gained.

It should be stated, however, that if a system approach complied with all three of the above functional requirements, unequivocal proof of illegal dumping operations would be obtained which in all likelihood would hold up in the courts.

2.4 PERFORMANCE REQUIREMENTS

2.4.1 Location Accuracy

The N.Y.D.C.E. has stipulated location of the vessel at the occurrence of dump be known to the following accuracy:

Present Dump Sites (Near Shore): 0.5 n.m., 2 σ

Future Dump Sites (at 100 N.M.) 5 n.m., 2 σ

2.4.2 Dump Detection

The detection of dump, if used in a system candidate, shall have a probability of detection of 95% throughout the entire dump mission.

2.4.3 Data Recording Subsystem

The data recording subsystem onboard the dump vessel or tug shall have a probability of successful recording of measured data greater than 95%.

2.5 SAFETY REQUIREMENTS

2.5.1 Fire Protection and Prevention

The design of the dump monitoring system shall consider the safety aspects of the vessel crew as well as fire protection and prevention aboard the dump vessels. The equipments considered for the candidate systems are primarily electrical devices and suitable fusing of ship's power signals and interface wiring will be provided for all equipments to negate the occurrence of electrical fires. In addition, the system design shall be configured to provide fail safe electrical circuits wherever feasible, and shall not utilize components which give off noxious or combustible gases at elevated temperatures.

2.5.2 Electrical Shock

The dump monitoring system shall be wired to minimize shock hazards and all equipments shall be electrically grounded aboard the vessel. Knobs and switches on electrical equipments shall be fabricated of non-conducting material such as phonolic or plastic compositions.

2.5.3 Dump Sensors

Utilization of dump sensors requiring modification of vessel piping, such as draft sensor or flowmeter, will be installed inboard of existing sea cocks and valves to assure safety of the vessel.

SECTION 3.0

SYSTEM APPROACHES

To effectively aid in enforcement of ocean dumping regulations, the Dump Monitoring System (DMS) must measure the location where dumping occurs. Furthermore, the DMS must have a high legal effectivity such as would be provided by unquestionable data recorded from a tamperproof system.

In this planning program, SSD conducted, for the Corps of Engineers, a planning program leading to the identification of a preferred DMS based on a systematic examination of the most promising candidates. The system approaches are presented in this Section 3.0 without reference to specific equipments. The rating techniques and evaluation of candidates are presented in subsequent sections. Hardware and Installation Specifications are presented in Appendices D and E. An implementation plan for the recommended DMS is presented in Section 12.0.

3.1 DUMP DETECTION

Since the Dump Monitoring System (DMS) is to provide a means for monitoring ocean dumping of waste material, an elementary approach is that the system must monitor the occurrence of a dump. This can be done in several ways, as follows.

(1) The captain can record and certify data indicating the start and completion of the dump. This involves a minimum of hardware and thus represents the most reliable approach, considering equipment factors only. It is recognized, however, that the approach depends upon human activity and that the captain is subject to the normal human frailties.

(2) Vessel draft can be sensed and recorded. The draft can be measured and integrated to avoid wave problems. This approach requires hardware and probably modification of the vessel (although most vessels do have sea water intake lines which could be tapped shipboard of the sea-cocks thus permitting installation of the draft sensing system without drydocking the vessel). Even though some vessels do take on sea water ballast, it has been determined that sensing change in vessel draft would yield a positive determination of the occurrence of a dump.

(3) Sea water chemical or physical properties could be monitored for change upon occurrence of dump. Where the waste material does not result in a significant measurable change in sea water properties, dye or a safe radioactive tracer could be added to the waste material to be sensed in the sea water after dumping. This approach is quite awkward to manage and difficult to make tamperproof and accordingly was quickly discarded. However, it should be recognized that the use of various radioactive tracers does permit identification of the dumping vessel and might further be useful in a determination of the waste matter dispersion and water transport mechanics.

(4) The status of dump line valves, dump doors, dump pumps, dump actuators, etc., can be monitored. This approach to sense the occurrence of a dump is valid. During the study, many

vessels were examined and it was determined that, without exception, the required instrumentation existed or could be readily added to sense the status of such valves, doors, etc.

3.2 LOCATION

The location of the actual dump must be measured by the DMS. This is most readily accomplished by measuring the position of the dump vessel or tug, using any of the following techniques, as further discussed in the candidate systems described in Section 4.0.

(1) Basic vessel navigation - as certified by captain.

(2) Radar Position Fix - ashore or on-board

(3) Radio Direction Finding - ashore or on-board

(4) Hyperbolic Radio Aids - Omega, Decca, Loran.

(5) Specialized Hyperbolic - Using multiple DMS shore stations.

(6) Specialized Proximity - Radio, sonar and transponders.

The difficulty of manipulating any recorded data varies with the candidate technique, but in all cases the candidate is considered relatively tamperproof wherever a continuous timed record would be kept showing vessel position enroute to and from the dump area. It would be extremely difficult to fabricate such a timed record if automatically printed on DMS equipment owned by the Corps of Engineers, and the system evaluation procedures must be responsive to candidates offering such features.

3.3 MONITORING AND REPORTING

The monitoring of ocean dumping operations using the DMS can involve real-time or after-the-fact reporting of data, or a combination of both. Real-time recording of data is generally expected for most candidates. However, the characteristics of the candidate DMS will determine whether reporting to the Army Corps of Engineers will be accomplished in real-time (eg. just prior to dump) or post-occurrence (eg. within 12 hours after return to port). Real-time reporting is most easily accomplished by a DMS where the basic position measuring equipment is ashore: if it is aboard the dumping vessel or tugs, real-time reporting usually involves telemetering of data ashore (thus adding costly equipment). Although real-time reporting allows control of permission to dump, it is suggested that the Corps of Engineers must then take care that their actions do not constitute a certification of vessel location, thus granting "approval" of the dump.

Post-occurrence reporting can be accomplished by delivery of recorded data by courier or by U. S. mails within, say, 12 hours after return to port. It is recognized that this approach does not afford a real-time action to prevent an illegal dump, but then, the Corps of Engineers is not legally charged with the responsibility to prevent illegal dumps and is not organizationally structured nor budgeted to do so. Post-occurrence delivery of data does not detract from the legal effectivity of the data and is not incompatible with providing the Corps of Engineers with the necessary control over the issuance of permits for ocean dumping of waste material. Accordingly, post-occurrence delivery of data is a perfectly acceptable system approach. Because it can provide a high legal effectivity, it does not detract from a system's strong deterrent effect in preventing improper dumps.

The operations associated with a review of the data after delivery must be considered. It would be desirable to have a recorded format compatible with machine readers. However, magnetic tape can be too easily erased and other approaches such as punched paper tape require costly machine readers. Furthermore, it would be desirable to have the data recorded in alpha numeric form in English language (with perhaps some simple coding if necessary) so that it is manually readable without difficulty. This is desirable so that there would be more legal meaning to the captain's signature (the data must be signed by the captain) certifying that the data delivered is valid . The Corps of Engineers personnel required to review and file the data can be kept to a minimum by using a format which would allow a quick overall review of each report, necessitating detailed examination of only those reports identified as suspect.

The items of data and events to be recorded are important and should include the following.

(1) Identification of vessel; load; place of departure; location of dump; owner; captain; and, valid permit.

(2) Date and time of leaving dock or loading site.

(3) Time of passing preselected inlet or harbor buoy and other well-marked buoys or navigation points.

(4) Vessel location (preferably continuous or frequent periodic).

(5) Dump sensing, as applicable.

(6) Time of start and completion of dump, entered by captain.

(7) Time of passing same inlet or harbor buoy on return trip.

(8) Date and time of return to dock or loading site.

(9) Status of DMS malfuction sensors, as applicable.

(10) Signature of captain certifying validity of data.

be as automatic as possible and require only very simple adjustment or operating procedure so that malperformance cannot be purposely made to occur without making the captain suspect.

In addition, operational practices would be defined to reduce costs for facilities, material, and personnel and would maximize the delivery of the data as described in Paragrsh 3.3 above. The operating procedures would place as little as possible additional burden on captain and crew and to encourage proper use, the DMS and operating procedures would desirably provide worthwhile information to the captain and would represent action he should be taking even if there were no DMS aboard (such as recording or logging of specific events, etc.).

There should be no operational restrictions invoked by the DMS. It should be an all-weather system capable of around-the-clock operation. It shall cover a wide area from the present dump sites (just past Ambrose light tower) to the edge of the continental shelf (or at least 110 miles into the Atlantic from Ambrose). It shall be useable for monitoring all ocean dumping, both self-propelled and towed. If possible, the DMS should offer a portable feature for occasional use on a vessel requiring minimal vessel preparation. If practical, it shall not require exchange of signals between a towed vessel and tug.

The equipment shall remain the property of the Corps of Engineers. Only very unsophisticated servicing (like replacement of fuses) shall be permitted by the captain. Insofar as is practical, positive alarms shall be provided to indicate malfunction of equipment. Captains shall report malfuctions promptly and upon the return of the vessel to port, the Corps of Engineers shall promptly effect a repair of reported malfunctions so as to

minimize delay to vessels. The DMS equipment, insofar as practical, shall employ a plug-in concept to facilitate quick replacement. The dockside repairs will normally be limited to replacement of plug-in units. Detailed repair of the faulty units shall be accomplished in a Corps of Engineers repair shop or at the manufacturer's facilities.

There is no practical DMS which will provide monitoring of a secretly made ocean dump. Accordingly, it is necessary to assure that every captain report each sea dump. The present procedure, requiring the captain to report his activity to the harbormaster should be continued with a periodic check made of his log versus reported data. It is also expected that the present practise of using patrol craft will also be continued so that captains will know that they might be spotted leaving the harbor. Very stiff action and high fines should be imposed for unreported dumping.

Finally, it should be stressed that the DMS operations and maintenance, like the DMS equipment, should be kept as simple as practical.

SECTION 4.0

CANDIDATE SYSTEMS

4.1 RATIONALE IN CANDIDATE SYSTEM SELECTION

Critical evaluation of the alternative approaches for the selection of promising system candidates involves an objective assessment of design characteristics; performance capabilities with respect to significant design features; and system requirements specified for the DMS. Desirable design features considered in this selection are shown in Table 4-1.

TABLE 4-1 LIST OF DESIRABLE DESIGN FEATURES

Feature No.	Feature
1	Positive detection of violations
2	Simple operating procedures
3	Minimal equipment
4	Reliable, proven equipment
5	All-weather operation
6	Common equipment for different vessels
7	Compatible with present and future dump requirements
8	Simple maintenance
9	Easily made operational
10	Tamperproof
11	High legal effectivity
12	High cost effectivity

In Table 4-2 is shown a listing of the various system approaches reviewed in the selection of those system candidates for further examination. Table 4-3 presents a matrix showing the approximate ratings (excellent, good, fair, poor, or no capability) for the various approaches. It will be readily observed that the first five candidates offer the most promise as DMS candidates.

TABLE 4-2. VARIOUS SYSTEM [illegible]

Approach No.	Techniques for Position Fixing/Dump Sensing/Recording Data
1	Hyperbolic Radio Nav System/on-board dump sensing/ on-board recording.
2	Ashore radar/on-board beacon activated by dump sensors/ ashore recording.
3A	Ashore Radio Direction Finding against an on-board transmitter activated by dump sensors/ashore data recording
3B	Same as (3A) but with captain confirming the dump occurrence by signalling on on-board transmitter.
4	Same as (1) but with data telemetered ashore for recording.
5	Dead-reckoning using existing on-board navigating equipment/on-board dump sensing/on-board recording.
6	Same as (5) but using inertial navigator.
7	Same as (5) but using Doppler Sonar Navigator
8	Same as (2) but with the radar and recording aboard a helicopter plus visual monitoring of dump.
9	Satellite navigation/on-board dump sensing/on-board recording.
10	Airborne multispectral photography and visual monitoring of the vessel and the dump.
11	Minimal system; review of on-board logbooks for vessel time of departure, arrival and dump.
12	IFF transponder or radar beacon on buoy at dump site interrogated by dump vessel/on-board dump sensing/ on-board recording.
13	On-board RDF using existing ashore transmitters/on-board dump sensing/on-board recording.
14	On-board range-range systems against special off-board transponders/on-board dump sensing/on-board recording.
15	Same as (12) but using SONAR transponders implanted at dump sites interrogated by vessel sonar range-measuring system.

TABLE 4-3 APPROXIMATE RATINGS OF VARIOUS APPROACHES

Approach No.	Feature Number 1	2	3	4	5	6	7	8	9	10	11	12
1	G	G	G	G	G	G	G	G	G	G	G	G
2	G	G	F-G	F	F	F-G	P	F-G	F-G	G-E	E	F
3A	G	G	F-G	G	F-G	F-G	F-G	G	F-G	G	G	F-G
3B	G	G	F-G	G	F-G	F-G	F-G	G	F-G	G-E	G-E	F-G
4	G	G	F-G	F-G	F-G	G	G	F-G	F-G	G-E	E	F-G
5	P-F	G	E	F-G	G	F-G	G	G	G	P	F	F-G
6	F-G	F-G	F	P-F	G	F-G	G	F	F	P-G	F	P
7	F-G	F-G	F	P-F	G	F-G	G	F	F	P-G	F	P
8	F	F	P	P-F	NC	G	G	P	F	G-E	G	P
9	P	F	F	F	F-G	G	G	F	F	G	F	P
10	P	F	P	P-F	NC	G	F	P	P	E	P-F	P
11	NC	G	E	E	E	G	P	E	E	P	P	P-F
12	G	P-F	F	P-F	G	F-G	F	F	P	F-G	G	P
13	F	F	F-G	G	F-G	G	F	G	G	F-G	F	P-F
14	G	F	F	F-G	F-G	G	F	F-G	F	F-G	F-G	P
15	G	P-F	F	F-G	F-G	F-G	F	F	P	F-G	G	P

In system approaches 1 and 4, several hyperbolic radio navigation systems are presently available differing in measurement technique, accuracy, and depending on system manufacturer, automaticity and cost. Among the more promising systems are Omega, Differential Omega, Loran C, Loran A and Decca. Each of these systems are potential candidates and therefore, each will require individual evaluation.

Omega, described in greater detail in Appendix C-1, utilizes phase difference comparison of 10.2 KHZ signals (single frequency system) from shore based receiver stations resulting in isophase lines (or lanes) formed every 8 nm. Lane ambiguity is generally accomplished through dead reckoning and automatic lane counting. For the dump monitoring system, continuous or periodic recording of data, including time, will provide a means of discerning lanes. With two and three frequency receivers (10.2, 13.6 KHZ and 10.2, 11.33 and 13.6 KZ), lane ambiguity is increased to 24 and 72 nm, respectively. Accuracy of Omega depends upon propagation variations influenced by ionospheric activity and will depend on specific path, time of day and time of year. Corrections of the propagation variations based on a prediction model is available in tabular form, diurnally in one hour increments, as a function of geographic location (known as Skywave correction tables) and results in a hyperbolic line-of-position (LOP) accuracy of approximately 1-2 n.m., 1σ depending on geometry and time-of-day. Present day costs of Omega receivers range between $6,000 and $9,500 which, along with its reasonable performance over long ranges makes it a potential candidate.

Tests performed by SSMD on three Omega receivers aboard the NYDCE vessel "Hocking" has demonstrated the feasibility of using an Omega navigational system for the Dump Monitoring System.

Differential Omega is a system concept used to predict spatial propagation error variations based on an Omega receiver located at a known geographic site (monitor system). It is assumed that the vessel receiver is experiencing the same variational errors as the monitor thereby removing the time dependent errors. Accuracy of fix using a Differential Omega system is improved by a factor of approximately 4:1 over conventional Omega. Requiring only one additional remote Omega receiver (two for reliability enhancement) the Differential Omega system provides excellent positional accuracy for a negligible increase in system cost. (Note: The monitor Omega receiver will serve the entire fleet of dump vessels.) For this reason Differential Omega will be selected over conventional Omega as a system candidate.

Loran C has been used aboard Naval vessels as a long range navigation system for some time and therefore merits consideration as a system candidate. This hyperbolic radio navigation system is based upon the time of arrival of pulses from two pairs of Loran stations (one master and one slave pair) to determine vessel location with an on-board receiver. Unlike the Omega system, Loran C does not have ambiguity problems in determining fix location (except for one point which is a mirror image but is sufficiently extended in range to dismiss its possibility) but it does require search and lock initialization procedures performed either manually or automatically with more expensive receiver equipments. Since Loran C utilizes pulse techniques (operating frequencies of 100 KHZ), skywave contamination can be avoided although care must be taken to assure lock-on at ground wave signal. Errors resulting from signal propagation over different paths between stations and the on-board receiver (called secondary phase corrections) however, are significant and must be considered for high accuracy performance.

With secondary phase correction and proper synchronization of master and slave ground wave signals, accuracy of Loran C is better than 0.05 nm for reasonable crossing angles. One difficulty of Loran C for the vessel locating subsystem stems from the severe operational environment imposed on the Loran C receiver in the New York/Manhattan Island area. Along the East, Hudson and Rahway river areas, the signals will be contaminated by atmospheric noise, and signal interference from steel structures and bridges will cause the receiver to lose lock while in the automatic tracking mode. This is further aggravated since the Loran station slaves are located 500 to 800 nm from the master and signal strengths vary significantly over different propagation paths. The Dana Air Force Base slave station, for example, must travel over land whereas the Cape Fear and Nantucket stations' propagation paths are primarily over water. Initialization and acquiring "lock-on" of the Loran C receiver may be difficult for these reasons and the operator could erroneously lock-on to the skywave signal rather than the ground wave; the one-hop E-skywave signal may be stronger than the ground wave signal which, in the presence of noise, may be erroneously acquired. With proper training and experience, however, it is anticipated proper acquisition could be made. It should be noted that it is not necessary that the receiver always track in the New York and New Jersey river areas providing reacquisition of station signals in better signal areas is operationally simple. It is desirable however, that a check on proper functioning of the Loran receiver be made at the loading pier and that prior to leaving for the dump site, the captain can notify the NYDCK or Harbor

supervisor. Tests conducted by [illegible] during the study with two [illegible] Loran tracking receivers have shown that along the entire river front areas of Manhattan, at short distances away from steel structures, acquisition of both Loran C and Loran A signals was not difficult (Reference Appendix B). Thus, it is anticipated malfunctioning receivers could be readily detected while the vessel was still tied dockside. One primary advantage of Loran C (or Loran A) over an Omega vessel locating subsystem is the inherent capability of providing the vessel captain with a direct readout of positional information which could be useful for navigation and pinpointing location of the dump sight. While this advantage is not significant for present dumping operations where dump site locations permit utilization of on board radar and radio direction finder equipments, it is a strong consideration if the dump sites are extended to, say, about 100 n.m. where radars become ineffective and on-board RDF equipments have limited capability. On the basis of the above arguments, Loran has sufficient advantages and capabilities to warrant consideration as a vessel locating subsystem.

Loran A, a World War II development and predecessor of Loran C, utilizes a 2 MHz operational frequency which lies just above the AM broadcast band. Its operating principles are essentially the same as Loran C utilizing pulse techniques to discern between skywave and ground wave signals, but it is more susceptible to interference from broadcast stations. Due to the comparatively smaller distances of slaves and master stations to the dump sites, and since the slave signals will always appear to the right of the master, however, search and lock-on procedures are easier than Loran C. Loran A has been used on ocean vessels for many years

and vessel captains are familiar with its operation and capability. Due to the higher operating frequency of Loran A over Loran C, range capability is not as great and accuracy is somewhat less. Typical range capability is on the order of 500 n.m. with an accuracy of better than 0.5 n.m. for good hyperbolic crossing angles. Tests conducted on the Holco receiver showed good tracking capability in the New York area even under rather poor signal environments (Reference Appendix B). Low receiver costs coupled with reasonable performance and navigation aid capability makes Loran A a promising vessel locating subsystem candidate and is more desirable than Loran C due to the established ability of captains to operate Loran A.

The Decca system, further discussed in Appendix D, utilizes low frequency (70 to 130 kHz) continuous stable frequency signals from a master and three slave stations; each signal bears a fixed relationship to the frequencies of the other three stations. Phase comparison with an onboard receiver permits a hyperbolic LOP fix. The hyperbolic lines of equal phase differences are separated as in the case of Omega, into lanes. Lane ambiguity is resolved by comparing the fundamental frequency for each of the three phase comparison systems for half a second over a one minute period. Since the Decca system utilizes low frequencies and continuous wave transmission, skywave contamination is present which cannot be separated from the ground wave. Decca coverage is limited to areas in which the skywave strength does not exceed 50% of the ground wave which is typically 200 nm. Accuracy of Decca is dependent on range from master as well as diurnal and seasonal times. The 95% probable fix accuracy is reported to vary between 300 ft under optimal conditions to over several nautical miles with poor environmental conditions, poor crossing angles of the LOPS and extended ranges. The Decca system, is owned and controlled by an English company, and the receiver is only leased and serviced by Decca personnel. Decca has applied for a license from the FCC to shut down the present N.Y. chain for an anticipated relocation of transmitting stations to more favorable sites for marine navigation. Consideration of this possibility with a possible extended shutdown period and the realization of being dependent upon a foreign company leasing agreements with equipment installation, servicing and maintainability performed by their employees has discouraged further consideration of the Decca system as a candidate.

System approach 2 utilizes a shore-based radar in conjunction with a vessel radar beacon to determine vessel location, identity, and dump status. This system is similar to the IFF (Identification, Friend or Foe) secondary radar system used in World War II to identify friendly aircraft or ships. The vessel radar beacon is essentially a pulse transponder which, upon receiving a radar pulse, replies with a specially coded group of pulses to provide identification of the dump vessel and its dump status. Vessel location is determined from range measurements (time that has elapsed between transmission of the shore based radar pulses and the reception of the vessel beacon reply pulses) and bearing to the vessel is provided by the antenna beam directivity. The reply can be at a different frequency so that the radar display shows only beacon replies and is not cluttered by other signals.

Since high frequency transmissions are utilized with radar systems, this system is line-of-sight limited in range and therefore cannot be used for the longer range dump missions. If it is assumed that the shore based radar is located on the World Trade Center Building with an effective antenna mast height of 1,225 feet, the maximum range would be less than 50 n.m. for the most favorable weather conditions. For present dumping operations where the range is on the order of 10 n.m. from Ambrose, this system approach is feasible although its operational characteristics is highly dependent upon weather environments. Location accuracy of this system is primarily a function of the antenna beam width which, for better radar systems, can provide a bearing accuracy better than 1 degree; range accuracy is generally better than 1,000 feet. At the present time, none of the shore-based radar systems within the New York Bight area are applicable for the dump monitoring system and therefore this system approach will require development and acquisition of a new radar installation. This of necessity, will result in high initial equipment expenditures with an estimated cost of $500,000 exclusive of land, buildings, and installation and a long time schedule estimated at three to five years before the system becomes operational. Considering also that each dump vessel would require an on-board radar beacon and dump detection equipment with corresponding acquisition, installation operating and maintenance costs, this system approach is ex[illegible]ive and provides no growth capability for dump monitoring if present dump sites are extended to the continental shelf. However, this system approach can provide a navigation aid to the captain. For these reasons, system approach 2 will not be selected as a

prime candidate but is carried along in the rating of candidate systems for comparative purposes only for present dumping operations at short range dump sites.

System approach 3 is a two-bearing location determination system utilizing two shore-based radio direction finding stations and an on-board transmitter for transmission of vessel identity and dump status. A radio or telephone link from the RDF stations is provided to retransmit acquired data to a N.Y.D.C.E. processing center for computation of vessel location, data assimilation and recording. The signals transmitted from the dump vessel transceiver would be selected in the marine radio-telephone band of 2 to 3 MHz to assure adequate range capability. In this frequency band, skywave contamination and A-M broadcast station signal interference could reduce operational reliability of the system and measurement accuracy. Daytime bearing accuracy for an RDF system is under 1°, if calibrated, but could increase to 2° at night-time with skywave contamination. With this system approach, the RDF stations would be installed in Coast Guard stations selected on the basis of geometrical accuracy considerations; typically one might be installed at Jones Beach Coast Guard Station on Long Island and the other at Atlantic City Coast Guard station in New Jersey for short range dump sites. RDF equipment costs for two stations exclusive of land, buildings, and installation is approximately $100,000. This system approach provides continuous real-time monitoring of dump vessels and has navigation aid capability with reasonable location accuracy. Although requiring FCC or IRAC approval for operation, this system has sufficient merits to warrant further evaluation as a candidate system.

System approach 4, similar to system approach 1, utilizes a hyperbolic navigation system for vessel location but differs in that an on-board printer is not employed.

One variation of approach 1 would delete the dump detection (draft sensors and monitoring of dump actuators, valves, etc.). Continuous recording of the vessel location and time at specified intervals (every 6 minutes) permits a time history of vessel location for the dump mission. In this case, the events unit (contained on either the self-propelled dump vessel or the towing vessel) is activated by the captain when dump is initiated and when dump is completed. These events are recorded on a digital printer along with vessel location and time; the print interval during this time as well as other special events is changed to a 15 second cycle for a two-minute period so that the printout of the activated events are clearly evident on the recording. After the completion of dump, the print cycle would return to its nominal 6 minute print cycle. With this system, the captain would be required to review the recording of the dump mission and validate concurrence of recorded data with his signature. Thus, even though the occurrence of dump is not specifically detected and recorded, this system will monitor dump vessel position and time enroute to and from the dump sites thereby providing implicit evidence that the vessel actually dumped at the site (premature dumping is significantly deterred since there would not be any significant advantage in early dumping if the vessel had to go to the dump site anyway). Further, with recorded position and time, the dump vessel velocity is readily calculated which might provide a reasonable check of suspected premature dumping violators for cases where vessel speed varies with draft or load. The major advantage

of this system approach is its applicability to both towed barges and self-propelled dump vessels without need of customized installations for various types of barges and vessels. Thus, installation costs are minimal compared with other approaches. This system approach has much in its favor and will therefore be selected as a candidate for rating, although it must be remembered that it does not provide a positive measurement of draft which might be especially desirable for some situations such as for fluid wastes which might be"trickled out" on the way to the dump site.

The dead reckoning techniques considered in system approaches 5 through 7 utilizes on-board navigation sensors to provide vessel location information. System approach 5 is a minimum cost dead reckoning approach using the vessels own navigation equipment whereas system approaches 6 and 7 include an added inertial navigator and doppler sonar, respectively. In all of these approaches, occurrence of dump is detected with dump sensors and recorded together with vessel position. Critical evaluation of these dead reckoning approaches has shown that for long mission time durations, vessel location accuracy is poor even with some means of updating position such as a radar fix on Ambrose lightship. For approaches 6 and 7, the cost is high (about $50,000 for each) and reliability is poor. For system approach 5, the system is subject to manipulation since the captain is familiar with the vessels navigation equipment and presently used systems (gyrocompass and velocity derived from engine tachometer) are highly inaccurate. On the basis of the above factors, system approaches 5 through 7 were dismissed as candidates.

System approaches 8 and 10 utilize an airborne helicopter or aircraft. The major disadvantage of these system approaches results from

the inability of the aircraft to operate in all weather environments, since early dumping is probably more prevalent in bad weather conditions which would also preclude aircraft from flying. In addition, operating costs for aircraft surveillance are high. On the basis of these arguements, system approaches 8 and 10 will not be selected for further examination as candidates for the dump monitoring system.

System approach 9 incorporates a satellite navigation system aboard the vessel along with dump detection sensors and a recording sub-system. Several navigational techniques are available using satellites including angle tracking, range and range rate systems. These techniques differ in number of satellites used, vessel on-board equipments required and complexity of ground tracking stations. The angle tracking system requires an on-board antenna pointing toward the satellites transmitting signals. By establishing two or more lines of position from measurements of two or more satellites, a position fix is established. The angle measurements must be made with great precision an error of .001 radians corresponds to an error of 3 to 4 miles in the fix. In addition, vessel local vertical must be measured to about 20 arc seconds, a difficult requirement in itself. The range technique requires a ground station tracking a minimum of two satellites and sends coded signals to the vessel via satellite transmissions. A transponder aboard the vessel returns signals to the ground station via the satellites. A ground computer computes position by using measured values of ranges from the vessel to the satellites. The range rate satellite navigation technique measures Doppler shift of a received satellite signal as a function of time and, with an on-board vessel computer, vessel position is computed on-board.

All of the above techniques require sophisticated equipment either on-board the vessel or ground stations and acquisition and operating costs for such systems are high. In addition, satellites for the proposed approaches are not as yet available for 24 hour continuous coverage. Accuracy of these systems is on the order of 1 to 2 miles with simple computers but can be several tenths of a mile with a complex computing system. For the sea dump monitoring system, the use of satellite navigational techniques is too sophisticated and costly compared with other system approaches and therefore, will not be considered further.

In system approach 12, surface buoys implanted at the dump sites containing either an IFF or radar beacon transponder responds to interrogated signals from the vessel, and range to the buoy determined with an on-board processor; on-board dump sensors provide detection of dump occurrence. A digital printer is used for recording position and dump occurrence. This system approach does not provide continuous monitoring of dump vessel positions enroute to the dump site and thus navigation aid capability for the captain cannot be provided. The major disadvantage of this approach, however, stems from the requirement of implanting buoys which, for the long-range dump site, is difficult and costly due to the greater depth of the ocean. On the basis of the above arguments, this approach will not be considered as a candidate for the DMS.

The log entry system, approach 11, is a minimal dump monitoring system approach in which the captain is required to enter into the ships log the time of significant events such as leaving dock, passing Ambrose, dump started, dump completed, and return to harbor. The logged data could be augmented with additional facts such as engine tachometer, ship heading,

etc. In addition, identifiable markers submersible after a period of time which the captain would be required to leave at the dump site for subsequent surveillance by a DOE patrol craft could be considered with this system approach. Although the deterrent value of this system approach cannot be readily measured, one major disadvantage stems from its legal ineffectiveness in the prosecution of violators. It is believed that the high degree of human involvement is too critical to the success of this system approach and therefore it will not be selected as a candidate.

System approach 13 utilizes an on-board radio direction finding equipment, dump sensors and a recording subsystem. In this approach, the vessel RDF will provide bearings to two available shore transmitting stations geographically located so that vessel position can be determined. The bearings, dump status and ship heading will be recorded at periodic intervals. The vessel location accuracy using this system approach depends on the vessel heading accuracy of the gyrocompass and the accuracy of the on-board RDF equipment. Vessel location accuracy using this approach is poor, in the order of 10-15 n.m. at dump sites 100 n.m. off-shore. In addition, the system can be easily manipulated if the captain is required to operate the RDF equipment and operational reliability in severe weather conditions is poor. For the above reasons, system approach 13 will not be considered a candidate for the DMS.

Range-range systems such as would be used for approach 14 are presently available as complete location systems designed primarily for off-shore survey and drilling operations. This equipment is not suitable for the DMS because it is operationally applicable to only a single vessel. Thus this approach will not be considered as a candidate.

System approach 15, which utilizes sonar buoys or a sonar transponder implanted on the ocean bottom, suffers from the same deficiencies cited in system approach 12. Furthermore, the range is short and not dependable. Accordingly, this system approach will not be selected as a candidate for further examination.

Table 4-4 presents a summary of the candidate systems selected for the Dump Monitoring System. Complete description of these candidates is presented in Section 4-2.

TABLE 4-4. SUMMARY OF CANDIDATE SYSTEMS

System Candidate	Location Subsystem	Dump Detection Subsystem	Recording Subsystem
1A	Differential Omega	Draft Status, Events Units, Actuator and Door Switches	On-board Digital Printer
1B	Loran C	Draft status, Events Units, Actuator and Door Switches	On-board Digital Printer
1B'	Loran A	Draft status, Events Units, Actuator and Door Switches	On-board Digital Printer
1C	Loran A	Events Unit	On-board Digital Printer
2	Shore Based Radar with On-board Radar Beacon	Draft Status, Events Units, Actuator and Door Switches	Shore Based Processing and Recording
3	Shore Based Radio Direction Finders with On-board Transmitter	Draft Status, Events Unit, Actuator and Door Switches	Shore Based Processing and Recording
4A	Differential Omega	Draft Status, Events Unit, Actuator and Door Switches	Dump Vessel-to-Shore Data Link, Shore Data Processing and Recording

4.2 DESCRIPTION OF CANDIDATE SYSTEMS

This section presents a description of the selected system candidates for the DMS which are evaluated in detail in subsequent sections of the report. Each candidate is identified by the numerical code previously assigned in Table 4-4. The equipment complement utilized by each candidate system including both dump vessel and shore base equipments (if any) are shown by the candidate system functional block diagrams. Details and operational procedures for the candidate systems are presented in the text.

4.2.1 Candidate 1A - Differential Omega with On-Board Dump Sensors and Data Recording

This system candidate utilizes an automatic Omega receiver aboard the dump vessel for position fixing, a draft measuring unit and (if needed) dump control sensors to monitor the occurrence of dump and an automatic digital printer for data recording. In addition, an "events unit" is provided to denote selected events which serves to identify and correlate recorded data, at the shore center. The shore-based equipments include an Omega receiver and digital printer which provides a means of correcting for certain sky-wave propagation errors to enhance vessel location accuracy.

The vessel on-board system operates automatically except for the requirement to manually enter time via the events unit prior to leaving the dock. The real-time Omega Receiver outputs relative lines of position (LOPS); relative time; and, operating status which are periodically recorded, after conversion to BCD format, on the printer. The print interval is set to automatically printout at a preset time interval or upon a print command signal from the events unit. At these print intervals, the

output of the dump vessel draft sensor (as well as status of monitored valves, actuators, etc.) are also recorded. The draft sensor consists of pre-set pressure switches appropriately fitted to the available sea chests or sea-water pipes providing measurements of vessel draft at approximate steps of 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16 and full load. The pressure switches are connected directly to the digital recorder to provide a print-out on one channel (or is connected to a resistor bank to provide a stepped current for an analogue recorder aboard a towed scow).

The events unit provides a means for the captain to set in time when leaving dockside for a dump and in addition, contains manual control switches to be depressed at selected events such as Leaving Dock, Passing Ambrose, Dumping Started, etc. The time as well as the selected events are recorded on the printer.

The digital printer is a 21 channel device utilizing BCD inputs and has an english language printout. Each channel has a 16-character print capability including numerical digits 0 through 9. Thus sufficient channels and characters are available to record all of the required DMS output data plus vessel identity and date.

The ashore Omega receiver LOP outputs provide accurate values of skywave corrections since the receiver location is known. It is necessary to periodically record the ashore receiver LOP data and time since the skywave corrections varies both diurnally and hourly. The sky wave corrections obtained from the ashore receiver is assumed to be applicable to the dump vessel Omega receiver data since mission ranges are comparatively small. Vessel location accuracy using this Differential Omega technique is considerably enhanced over a conventional Omega system approach and provides a 4:1 improvement in accuracy.

With this candidate system, the vessel on board recorded data (plus the scow data, if applicable) must be removed by the vessel captain and either mailed or courier-delivered to [illegible] for analysis and record keeping. The necessity for transporting paper records and manually analyzing data are limitations on the efficiency of this system. If a digital punch tape is utilized for both the ashore and dump vessel data recording, the data can be processed on a small digital computer thereby minimizing manual data processing. This approach was ruled out. However, a data link system from the vessel to the shore center is considered in system candidate 4 which eliminates both the need for delivery of paper records and for manual data processing. For candidate 1A, if a towed scow is the dumper, the tug need not have the Draft Sensor Unit nor any Dump Status monitors. See Figure 4-1 for the Basic Block Diagram.

4.2.2 [illegible]

This system is identical to candidate system 1A except Loran C is used for the vessel location subsystem. The equipment suit comprises two Loran C automatic tracking receivers (one for each LOP), a draft sensing unit, dump status monitors (as needed), an events unit and a digital paper tape printer. With this system, no ashore equipments are required since propagation error corrections are not necessary. In addition, the Loran C time difference LOPS are displayed by the receivers and can serve as a navigation aid to the captain. Operational procedures with this candidate are similar to system candidate 1A except the captain is required to acquire and "lock on" to the Loran C stations. Further, since relative time is not outputted from the Loran receivers, as provided with Cargo,

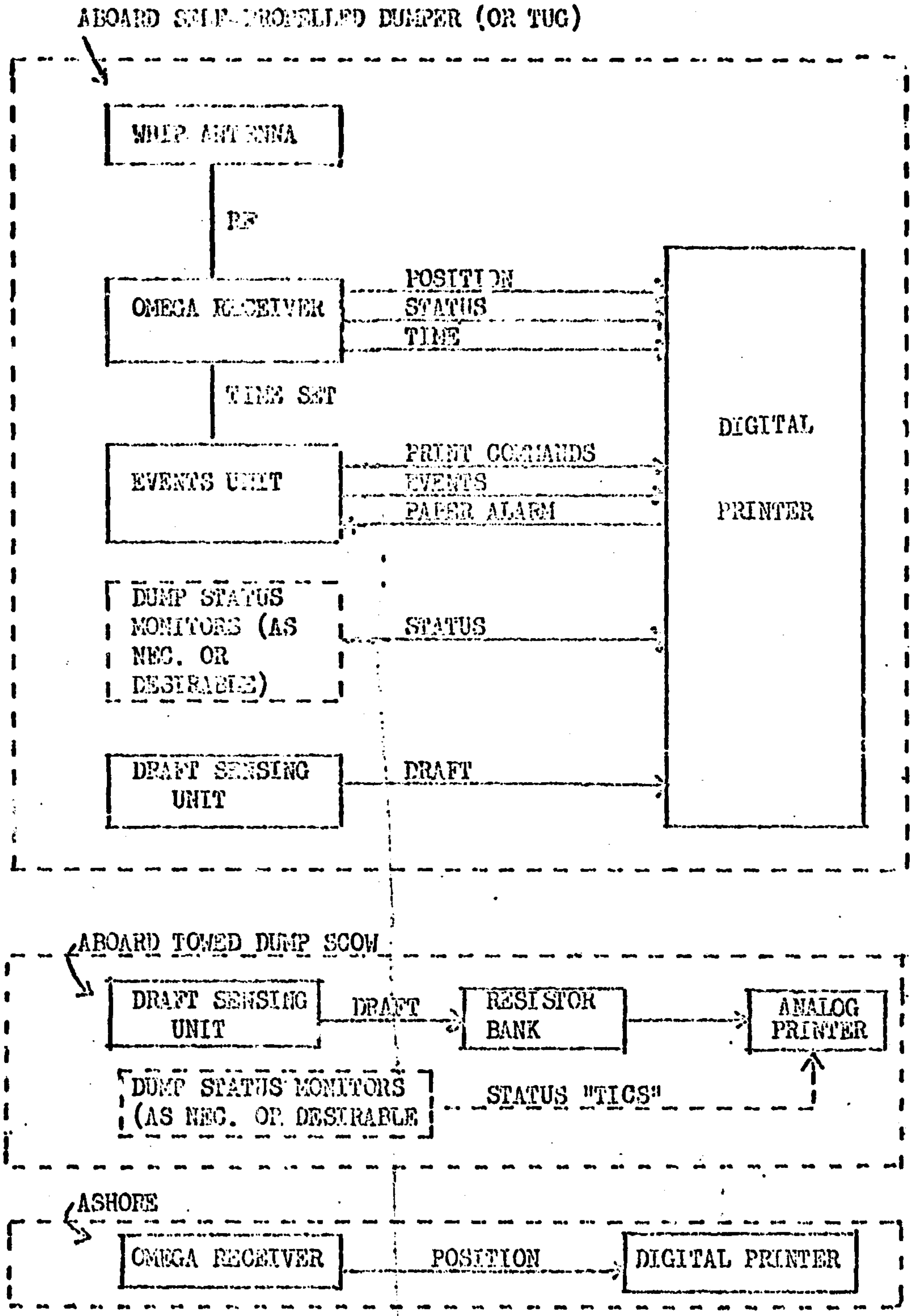


FIGURE 4-1

CANDIDATE 1A BASIC BLOCK DIAGRAM

a digital clock is required with this candidate system. The clock can be incorporated within the Events Unit and elapsed time outputted to the printer in BCD format. The basic block diagram for candidate 1B is shown in Figure 4-2.

4.2.3 Candidate 1B' - Loran A with On-board Dump Sensors and Recording

This system is identical to candidate 1B but Loran A is used instead of Loran C. See also Figure 4-2. Here again, the Dump Status Monitors and the Draft Sensing Unit are not required aboard the tug towing a dump scow.

4.2.4 Candidate 1C - Loran A with On-board Data Recording

Since this system candidate does not utilize on-board dump sensors, it is perhaps one of the simplest approaches for a DMS which will normally provide sufficient recorded evidence for legal action or license revocation of violators.

This system candidate is comprised basically of two Loran A automatic tracking receivers, an Events Unit with digital clock, and a digital paper tape printer. A functional block diagram of this candidate is given in Figure 4-3. Operational procedures with this system require the captain to "lock-on" to the Loran A station signals and to activate the control event switches on the Events Unit at certain times. As in system candidates 1A, 1B, and 1B', the printer will record data at pre-specified intervals and upon the entering of Events.

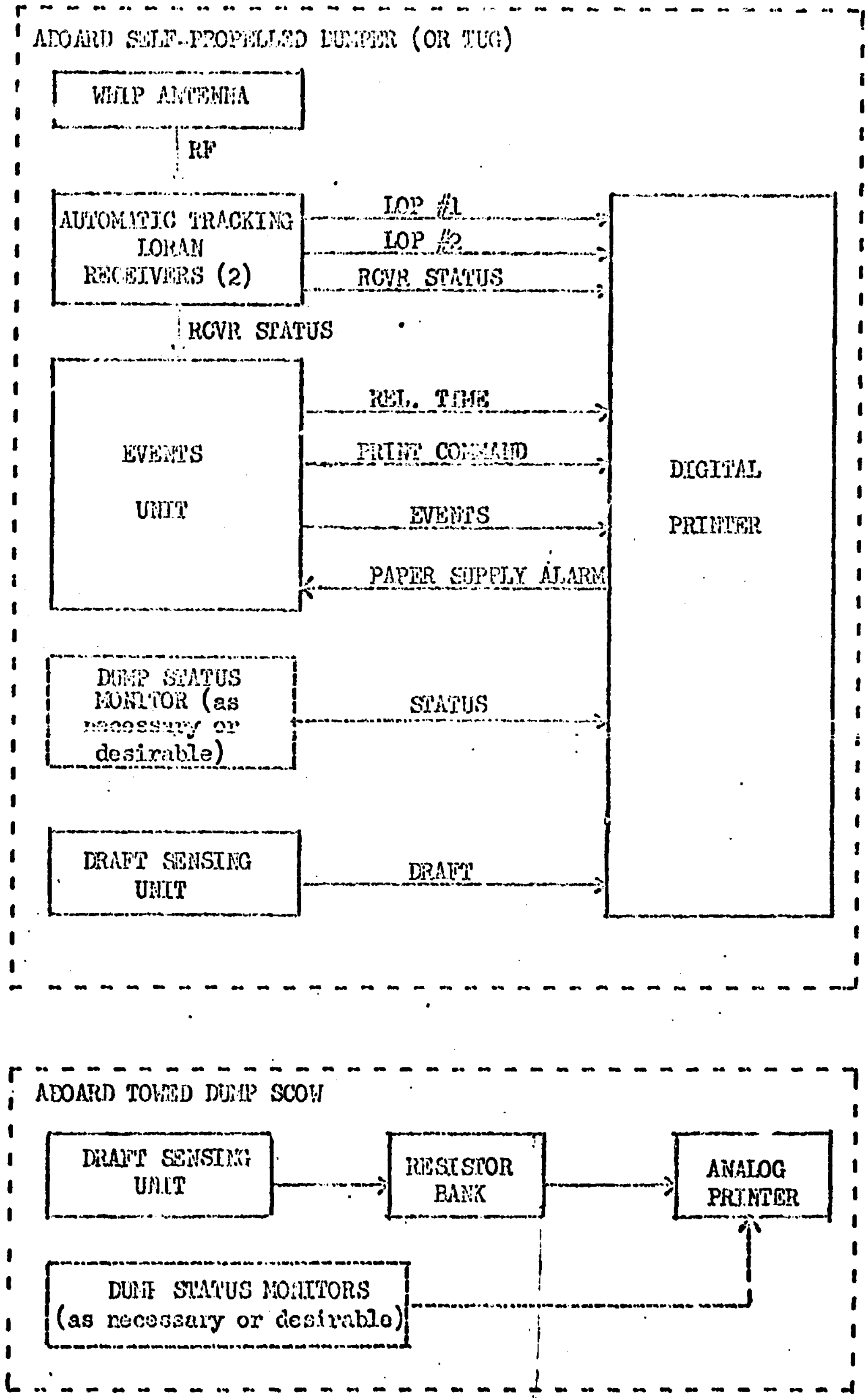


FIGURE 4-2

BASIC BLOCK DIAGRAMS FOR CANDIDATES 1B AND 1B'

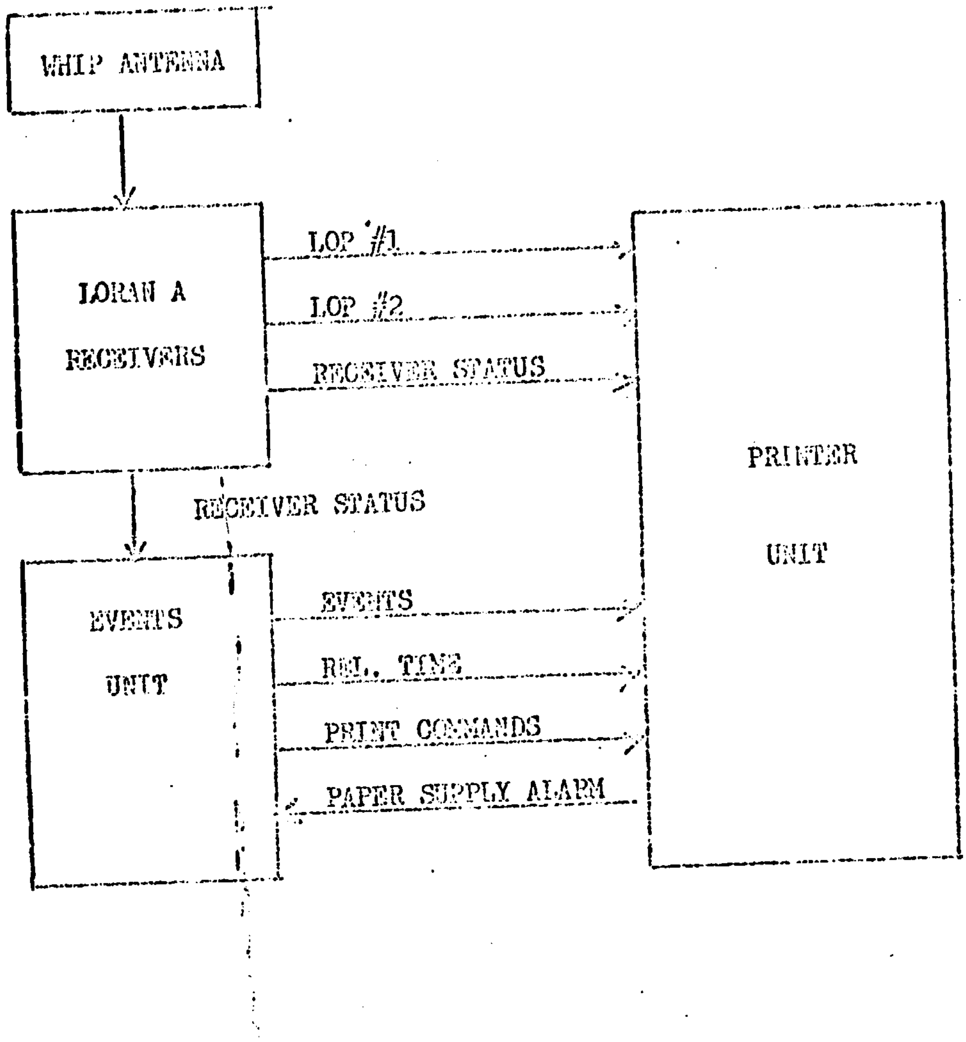


Figure 4-3

Candidate 1C Basic Block Diagram

4.2.5 Candidate 2 - Shore Based Radar with On-board Radar Beacon and Dump Sensors

This system candidate utilizes a shore based radar interrogation/receiver station in conjunction with an on-board radar beacon transponder and dump sensor equipments to provide vessel identity, vessel location and dump status data to the radar station. Since the data is made available at the shore station, this system does not require an on-board recording system and provides real-time dump monitoring, ie. a dumping violation is detected at the time of its occurrence. This system is similar to the ATCRBS (Air Traffic Control Radar Beacon System) currently used in the U. S. for air traffic control. In principle, the shore based radar station transmits an interrogation signal to the vessel on-board radar beacon transponder which if set to respond to the interrogation signal, transmits a coded reply signal back to the shore receiver. The transponder reply codes currently in use provides two framing pulses 20.3 microseconds apart with 12 information pulses between them resulting in a system capable of producing 4096 different coded replies. In addition, a special position identification (SPI) pulse may be used with any of the 4096 codes. A much simplified transponder reply code would be required for present ocean dumping operations. The interrogator code could be that presently unassigned for civil applications and is comprised of 2 pulse pairs 25 microseconds apart.

The data processing and display center located at the radar station could be either a manually operated center which utilizes conventional PPI displays or an automatically operated center utilizing

digital computers and printers. In the former case, an operator would view the PPI display of vessel radar returns with additional markings to identify the transponder reply code and ascertain vessel location periodically during the mission. A camera system could be utilized to record the vessel location at various times for legal evidence. With an automatically operated center, a digital computer would permit continuous storage of each vessel position, dump status, etc. and subsequently print out the data at periodic intervals. With a computer, a summary record of all vessel dumping activity over a given period could readily be provided. For example, for a specified time period, the computer can print out vessel identity, number of trips made, number of violations, date and time of each violation, etc. For purposes of the present study, it is assumed a manual center will be utilized.

The on-board dump sensor equipments consist of the draft sensing unit, the events unit, and the dump actuation status monitors (if necessary or desirable).

4.2.6 Candidate 3— Shore Based RDF Stations with On-board Transmitter and Dump Sensors

This system candidate utilizes two shore based RDF stations to determine vessel location from signals transmitted from an on-board transmitter. The transmitted signals are modulated to contain the vessel dump status and its identity. The received signals at shore are converted to digital format using a frequency-to-digital convertor. The RDF stations considered to be located at two available Coast Guard stations selected on the basis of geometrical accuracy consideration, is assumed to contain

an eight aerial Adcock H. F. Direction Finder System utilizing a radio-goniometer to extract vessel bearing. This bearing data is retransmitted on a telephone or radio link to a central processing center where the vessel identity, dump status and bearing data are correlated and recorded on a digital printer.

Since the processing center will receive data from many vessels over time periods ranging from 6 to 36 hours depending on dump missions which may overlap, this system will require a digital computer for data assortment and correlation. In all likelihood an I/O multiplexer will be required to handle received data. The computer also permits computation of vessel location from the two bearings taken at the selected RDF stations as well as serving as a general storage record for an individual dump vessel.

The on-board dump sensors selected for this candidate system are the draft sensing unit, dump status monitors (as needed) and an Events Unit. No on-board digital printer is required; the data is telemetried for recording ashore, using modulation of the same transmitter used for rdf.

4.2.7 Candidate 4 - Differential Omega with On-board Dump Sensors and Vessel/Shore Data Link

System candidate 4 is similar to candidate 1A except a data link is provided to transmit dump status, vessel LOPs and vessel identity to a shore center. The digital printer and the requirement to insert initial time as utilized in candidate 1A are not necessary. For the same reasons discussed in paragraph 4.2.6, this system candidate requires a digital processor and an I/O multiplexer at the shore center for data correlation, computation and storage.

SECTION 5.0

EVALUATION AND ANALYSIS TECHNIQUE

In comparing various system approaches and in rating selected system candidates, an evaluation technique was employed which addresses itself to those aspects of the sea dump monitoring system which are significant and reflect differences in the systems examined. A uniform capability in all systems would change the level of the evaluation but the relative comparison would remain the same. As an example, if all systems have the same legal effectiveness, the overall score magnitude of each system with legal effectiveness considered would change but the relative positional rating would be the same.

The evaluation technique selected for the comparative study is based on an overall score rating technique formed by the product of the subscore ratings and the average weighted subscore rating of significant system factors. Details of this rating approach is presented in Paragraph 5.1. In order to perform an unprejudiced evaluation of candidate systems, it was necessary to apply normalization of the input data to the overall score rating technique in accordance with the approach discussed in Paragraph 5.2

5.1 SYSTEM RATING METHOD

The overall score (OS) rating method is formed by considering a number of subscores (S_1, S_2, S_3, ---S_i) where each subscore includes the significant evaluation factors for the dump monitoring system. In equation form, the overall score can be written:

$$(5\text{-}1) \quad OS = \left[(S_1 + S_2 - - - S_n) / \sum_1^n W_n\right]\left[R_1 R_2 - - - R_n\right]$$

The advantage of this product rating method over other rating approaches (for example, sum rating) lies in the capability of eliminating a poor candidate early in the evaluation thereby permitting concentrated effort on the more promising candidate systems.

The subscores (S_1, S_2, ---S_n) are determined by the product of a weighting factor (W) and an assessment rating (R) for each significant evaluation factor. Thus, in general,

(5-2) $S_i = W_i \times R_i$

The weighting factor (W_i) serves to weight the evaluation factors in accordance with its relative importance to the overall system requirements. Cost effectiveness, for example, which is a measure of system performance relative to life cycle costs is weighted five times more significant in the overall score rating than automaticity.

The evaluation factors used in the overall score rating, established jointly by Sperry and the District Corps of Engineers, are as follows:

S_1 - Range of Coverage
S_2 - Legal Effectiveness
S_3 - All Weather Capability
S_4 - Automaticity
S_5 - Initial Cost
S_6 - Cost Effectiveness
S_7 - Location Accuracy
S_8 - Design Factors
S_9 - Miscellaneous Factors
S_{10}- Hardware Availability

These factors are discussed in detail, including assigned weighting factors and ratings, in paragraphs 5.1.1 through 5.1.10 which follow.

5.1.1 Range of Coverage (S_1)

The mission requirements presented in paragraph 2.3 has established the operational range of coverage to include both short range (10 n. miles) for present dump operations and long range (edge of the continental shelf) for future dump operations. To consider both range coverage requirements, the following rating scale was established. If the system candidate is capable of operating out to the continental shelf, a unity rating factor was assigned. If capable of operating beyond the continental shelf, the rating was increased to 1.1 to acknowledge increased system capability. Proportionately lower ratings are assigned with decreasing range coverage. Table 5-1 summarizes the assessment rating established in accordance with the above policy.

TABLE 5-1 RANGE OF COVERAGE RATING

SYSTEM CAPABLE OF OPERATING AT RANGES FROM:	RATING (R_1)
0 to Greater than 300 N.M.	1.1
0 to 100 N.M.	1.0
0 to 80 N.M.	0.9
0 to 50 N.M.	0.7
0 to Present Dump Sites	0.5
Less Than Present Dump Sites	0

The assessment weighting for the range of coverage factor is taken as unity so that $S_1 = 1 X R_1$.

5.1.2 Legal Effectiveness (S_2)

The legal effectiveness rating of a candidate system is subjective and is based on the credibility of the evidence in the courts.

The dump monitoring system is similar in several aspects to auto speed law enforcement using radar, and court rulings concerning legality and accuracy of these devices will provide some insight in the assessment of legal effectiveness of the candidate dump monitoring systems. Based on radar court case history, it is evident that the accuracy and reliability of the dump monitoring system being a new concept will be challenged in court and expert testimony attesting to its scientific principle, construction, operation accuracy and reliability will be required. In addition, readings and/or recordings of the dump monitoring system, in order to sustain a conviction, will require clear, convincing and unequivocal proof of its accuracy either by test records performed prior to and after violation or by multiplicity of recorded sensor data correlated in such a manner as to provide reasonable proof of proper functioning and operation of the equipments. A significant difference between the radar speed sensor system and the dump monitoring system is that in the latter system, continual monitoring of vessel position and dump status during the dump mission is provided; with the radar speed sensor, only a single piece of data is available which must stand alone as evidence. With periodic monitoring and recording of multiple sensors, correlation of the data package would probably provide convincing evidence of proper functioning and operation.

Assessment ratings assigned for the legal effectiveness sub-score S_2 is given in Table 5-2. The system weighting factor to be applied is taken as unity ($S_2 = R_2$). Since the primary objective of the dump monitoring system is to provide evidence for the enforcement of dumping regulations, the ratings were stringently set to rule out any candidate system which would not generally hold up in court.

TABLE 5-2 LEGAL EFFECTIVENESS SUBSCORE RATING

Data Effectivity in Court	Rating (R_2)
Air Tight Always	1.1
Generally will hold up in Court but not always airtight	1.0
Generally not likely to hold up in Court	0

5.1.3 All Weather Capability (S_3)

The all weather capability subscore reflects the capability of the dump monitoring system to perform in the service environment discussed in paragraph 2.2.3 The assigned assessment ratings are presented in Table 5-3 and the weighting factor selected for the overall system candidate score is unity ($S_3 = R_3$).

TABLE 5-3 ALL WEATHER CAPABILITY RATING

Impact of Weather on Performance	Rating (R_3)
Significant degradation occurs only for weather conditions which do not exceed.	
1% of time	1.1
2% of time	1.0
4% of time	0.8
5% of time	0

5.1.4 Automaticity (S_4)

The degree of automaticity of the dump monitoring system candidates is an important evaluation criteria factor from several standpoints. With a completely automatic system, vessel/barge crew operational participation would not be required thereby minimizing improper operation and abuse of system equipment. In addition, automatic systems will provide a deterrent to equipment tampering due to unfamiliarity of the system by the crew. Finally, an automatic system will be more readily accepted by vessel owners and the captain since participation by them would not be required or would be minimal at most, thereby not adding a work burden on them. The recommended assessment rating for the Automaticity subscore is provided in Table 5-4. The assigned weighting factor is chosen to be unity, so that $S_4 = R_4$.

TABLE 5-4 AUTOMATICITY RATING

Degree of Automaticity	Rating R_4
Fully Automatic After Power Turn-On	1.0
Requires Only Minor Attention of Captain/Crew at Unsophisticated Level	1.0
Requires Significant Attention of Captain/Crew and/or Considerable Techical Skill Level	0

5.1.5 Initial Cost (S_5)

This subscore is included to show sensitivity, if any, to initial cost or to rule out any system whose initial cost is above a tolerable amount (e.g., a budget limit). By agreement with N.Y.D.C.E., $R_5 = S_5 = 1.0$ for all DMS candidates.

5.1.6 Cost Effectiveness (S_6)

The cost effectiveness subscore is a measure of system effectiveness in deterring improper dumping relative to life cycle costs. As used in this study, it is defined as the normalized quotient of the weighted relative value of performance effectiveness of a candidate divided by the 5 year cost of ownership for the candidate. Mathematically, the cost effectiveness factor can be written:

(5-3) $N' = V_{DMS}/C_5$ where,

N' = Cost effectiveness factor,

C_5 is the cost of system ownership for a 5 year period and

V_{DMS} = the weighted relative value of performance effectiveness of a candidate.

The performance effectiveness measure, V_{DMS}, is related to the performance and operational characteristics of subsystems comprising the DMS candidate and is defined by the following equation:

(5-4) $$V_{DMS} = \frac{(W_{DD}P_{DD} + W_L P_L + W_R P_R + W_{DR}P_{DR} + W_E P_E)}{W_{DD} + W_L + W_R + W_{DR} + W_E}$$ where,

P_{DD} = Probability of Detecting Occurrence of a Dump

P_L = Probability of Locating Vessel to within Specified Accuracy

P_R = Probability of Correct Recording of Dump Information

P_{DR} = Probability of identifying improper dumps during normal data review

P_E = Probability of Effective Utilization of Data, and,

W_{DD}, W_L, W_R, W_{DR}, and W_E are weighting factors reflecting the worth of each subsystem in deterring illegal dumping.

The selection of subsystem weighting factors was based on a subjective evaluation of system worth assuming loss of each subsystem considered separately. If it is assumed, for example, that a recording subsystem used for a particular candidate is not functioning, its loss is more significant than say loss of the dump detection subsystem since without the recording subsystem, no surveillance is possible, whereas without the detection subsystem, some measure of dump surveillance is provided with recorded vessel location and time.

Using the above rationale, the following weighting factors were assigned:

Dump Detection Weighting - $W_{DD} = 2$

Location Accuracy Weighting - $W_L = 4$

Recording Weighting - $W_R = 4$

Data Review Weighting - $W_{DR} = 1$

Effectivity Weighting - $W_E = 1$

The probability of detecting the occurrence of a dump is a function of the specific dump detection approach used as well as the type, number and arrangement of sensors provided. Thus, the probability of dump detection using on-board sensors monitoring vessel draft, dump controls and dump activity, may be expected to differ from an approach only sensing draft. In addition, for a specified system approach, alternative arrangements of sensors are feasible (parallel redundancy, serial configuration, standby redundant configurations, etc.) so that the probability of dump detection, P_{DD} is determined by the system candidate specifics.

The probability of locating the vessel to within the accuracy specified for the system is utilized in the system effectiveness model. P_L depends upon the accuracy of the location system used and its operational state (operating capability). The operational state will depend on the reliability of the locating system equipments, the availability of these equipments at the time the dump vessel leaves dock, and the operational status of the equipment. Knowledge of the vessel track is considered to be about two times more important than sensing occurrence of a dump and thus is given a relative weight of 4.

The information must be preserved in some form for data processing. The probability of correct transmission and preservation of dump information is defined by P_R in the system effectiveness model. It should be noted that this probability depends not only on the unique features of the candidate system approach such as whether the data is recorded aboard the vessel or data linked to a shore station but also whether a self-propelled dumping vessel or a towed dumper (dredge or scow) is being considered.

The probability of correct data review, P_{DR}, reflects the probability of identifying improper dumps given recorded dump information. This probability depends on the method used in data recording and the degree to which automatic data processing can be utilized.

The remaining factor, P_E, is a measure of the credibility of the processed information and the penalty procedures instituted as a consequence of this information. The system will not be effective if either the processed information has no legal validity or if it is never used to indict

and prosecute an offender. The legal effectivitiy will depend, to a considerable extent, on the system approach used, whereas indictment and prosecution of a violator will be influenced by the manipulation and presentation of the data. An important consideration here is the validation of dump mission data by the captain. Legal effectivity and prosecution is considerably enhanced if the recorded data validated by the vessel captain is understood by him. In addition, the deterrent effect of a system requiring captain validation is believed to be formidable.

While the performance effectiveness criteria established in this section provides a reasonable system engineering approach for evaluation of a system candidate, several significant factors are not reflected in equation (5-4). Two of the major factors are timing and mission events. With these factors a chronological time history of the dump mission is provided which, even in the absence of other data, serves as a deterrent and can be utilized to provide some measure of assurance that the dump vessel did properly perform the mission. In addition, the timer is important in the overall system design since print commands to the printer are generated by the timer in several of the candidate systems. In the performance effectiveness analysis, it will be assumed that both timing and mission events are provided for all system candidates and that these factors will not change the relative ranking of the candidates and accordingly can be omitted from the analysis.

The cost of ownership, C_5, in equation (5-3) is the life cycle cost for a single system over a five year period based on an initial buy of 50 systems. The life cycle cost is comprised of the following.

- Acquisition Costs
- Costs for Spares
- Installation Costs
- Operating Costs
- Maintenance Costs

Generation of system candidate life cycle costs including stated assumptions and computing procedures are presented in Section 9.0.

The subscore for the cost effectiveness criteria is determined using an assessment weighting factor of five ($S_6 = 5R_5$) and a rating (R_5) from zero to 1.1 as calculated using the following Table 5-5.

Table 5-5

Cost Effectiveness Factor N' X 10^6	Rating R_5
Above 1.0	1.1
0.8 to 1.0	1.0
0.6 to 0.8	0.9
0.2 to 0.6	0.5
Under 0.2	0

5.1.7 Accuracy (S_7)

The accuracy subscore is based on the weighted average of subscores for the accuracy of measuring vessel location. Vessel location accuracy is considered on the basis of range to licensed dump areas from Ambrose Lighthouse. For present dump operations, a range of 10 n.m. is applicable, whereas future dumping regulations may extend dump areas to as far as 150 n.m. The assigned accuracy rating is presented in Table 5-6. A unity subweighting factor is applied to the location accuracy rating, so that $S_7 = R_7$.

TABLE 5-6 LOCATION ACCURACY

Error in Measuring Dump Location	Rating R_7
Under 0.35 n.m.	1.1
0.35 to 0.55 n.m.	1.0
0.55 to 0.7 n.m.	0.9
0.7 to 1 n.m.	0.8
Over 1 n.m.	0

5.3.8 Design Factors (S_8)

The design factor subscore is based on the weighted average of ratings assigned to design factors not rated elsewhere but each of which is significant from an overall assessment of system worth. These design factors, with assigned subweight, are presented in Table 5-7.

TABLE 5-7 DESIGN FACTOR SUBWEIGHTING

Factor	Subweight, W_i
Reliability	5
Maintainability	5
Weight and Size	1
Power Requirements	1
Warm-up Requirements	1
Service Environment Capability	2

Assigned ratings for the design factors are presented in Table 5-8. The overall rating is computed from the expression:

$$(5\text{-}5) \qquad R_8 = \frac{\sum W_i R_i}{\sum W_i}$$

where the subscript i denotes each design factor considered.

The weighting factor selected for the design factors score is taken as 2, so that $S_8 = 2\,R_8$.

TABLE 5-8. DESIGN FACTOR RATINGS

Factor	Rating R_i
Reliability, MTBF, HRS	
Over 500	1.1
400 to 500	1.0
300 to 400	0.8
150 to 300	0.6
Under 150	0
Maintainability, MTTR, HRS	
Under 1.0	1.1
1.0 to 1.5	1.0
1.5 to 2.0	0.9
2.0 to 2.5	0.8
2.5 to 4.0	0.6
Over 4.0	0
Weight and Size (on-board equip.)	
One-man portable	1.1
Two man or needs dolly	1.0
Needs crane, etc.	0.5
Power Requirements	
No special power required	1.0
Requires power not normally aboard dump vessels	0.3
Warm-up Requirements, Minutes	
Under 2	1.1
2 to 10	1.0
10 to 30	0.9
30 to 60	0.7
Over 60	0.2
Service Environment Capability (need for special external provisions to meet service conditions)	
None required	1.1
Only minor and easily accommodated	1.0
Significant but readily accommodated	0.7
Extensive	0.3

5.1.9 Miscellaneous Factors (S_9)

The Miscellaneous Factors subscore to be considered in the rating criteria comprise desirable features which enhance system worth but do not relate directly to system performance, cost, or the features considered in the design factors. These miscellaneous factors, along with assigned subweighting, are given in Table 5-9.

TABLE 5-9 MISCELLANEOUS FACTORS

Factor	Subweighting, W_i
Safety Features	2
Interchangeability	5
Installation Flexibility	2
Tamper Proof	10
Growth Capability, Range	1
Growth Capability, Nav Aid	1
Growth Capability, Accuracy	1
Training Required	1
Value as a Deterrent	3

Assigned ratings for the miscellaneous factors subscore are provided in Table 5-10. The subscore weighting is taken as 5 ($S_9 = 5\ R_9$). The overall subscore is computed using equation (5-6).

(5-6) $$R_9 = \frac{\sum W_i R_i}{\sum W_i}$$

TABLE 5-10 MISCELLANEOUS FACTOR RATINGS

Factor	Rating R_i
Safety Features	
Inherent and complete	1.1
Normal-requires some additional	1.0
Requires special additional	0.9
Requires extensive/special addl.	0.5
Considered very unsafe	0
Interchangeability	
DMS and units completely	1.1
Only similarly marked units completely	1.0
Only by selection	0.5
None	0
Installation Flexibility	
Usable on all vessels with only minor vessel preparation	1.1
Only minor vessel preparation, but minor customizing needed to make DMS usable on all vessels	1.0
Requires significant vessel preparation and/or customizing	0.8
Requires extensive vessel preparation and/or customizing	0.4
Tamper Proof	
Inherently tamper proof	1.1
Reasonably tamper proof and requires only minor additions to be acceptable	1.0
Only moderately tamper proof but if manipulated is readily apparant	0.8
Is easily manipulated and not readily apparant	0
Growth Capability, Range	
Growth Capability, Nav Aid	
Growth Capability, Accuracy	
Provided with no addl. equipment	1.1
Only minor equipment mod required	1.0
Significant equipment mod required	0.5
Not possible	0

TABLE 5-10 MISCELLANEOUS FACTOR RATINGS
(Continued)

Factor	Rating R_i
Training required (for correct operation), hrs.	
Under 1.5	1.1
1.5 to 4.0	1.0
4.0 to 8	0.9
8 to 16	0.8
16 to 40	0.5
Over 40	0
Value as a Deterrent (percentage of trips estimated that it keeps captain "honest" because he knows he is being monitored)	
Over 70%	1.1
50% to 70%	1.0
30% to 50%	0.8
Under 30%	0

5.1.10 Hardware Availability (S_{10})

The hardware availability subscore is based on an assigned weighting of unity ($S_{10} = R_{10}$) and ratings specified in Table 5-11.

TABLE 5-11 HARDWARE AVAILABILITY RATING

Status of Major Units	Rating R_{10}
Off-the-Shelf, no mods required	1.1
Off-the-Shelf, only minor mods or development needed (up to 10% of cost)	1.0
Off-the-Shelf, significant mods required (10 to 20% of cost)	0.9
Major mods or major development required	0

5.2 EVALUATION PROCEDURE

In order to perform the evaluation of DMS candidates, it was necessary to consider inputs from several sources. These include:

- o Field data and operational experience
- o Equipment performance characteristics
- o Analytical investigations
- o Experience with similar equipment

Since the overall evaluation seeks to compare DMS candidates differing significantly in system approaches used, it is important to assure that the data used for evaluation is normalized to the same base. Thus, while field data may be available for certain equipments presently operational, it cannot be used directly in a comparison with a system where only meager or no data is available. To achieve data normalization, the following procedure was used.

In the three key areas of performance, cost and equipment reliability, the input data was developed by a single specialist. Data was assembled from the above sources which was then reduced to a common base for all candidates. The equipment performance characteristics was obtained from a combination of analytical investigations and published information. Equipment reliability estimates were developed by combining field data, specification figures and comparison with similar equipments. Where subscore ratings involved subjective evaluation, the rating was established separately by more than one engineer and later compared to obtain a single evaluation. Section 10.0 presents a summary of the individual subscore and total score for the DMS candidate. Also described is the rationale and computational results leading to the ratings which are based on estimated values and analytical results presented in Sections 6.0 thru 9.0.

SECTION 6.0

PERFORMANCE ANALYSIS

6.1 LOCATION ACCURACY

The vessel location subsystems utilized in the selected system candidates include:

- Differential Omega
- Loran C
- Loran A
- Shore Based RDF With On-board Transmitter
- Shore Based Radar with On-board Radar Beacon

The first three vessel locating subsystems are hyperbolic radio navigation systems whereas the remaining two subsystems are two-bearing radio and radar range/bearing fix systems, respectively. The accuracy of vessel location for these subsystems was determined using the applicable mathematical techniques outlined in Appendix A. In this report, the accuracy of the vessel location subsystem is taken as the radial circular error (radius of uncertainty) in which 95% of the fixes will fall. Conversely, given the system location accuracy requirement, the probability of locating the vessel to within a specified circular error (radial error) may be determined. The latter problem must be considered for the cost effectiveness rating score.

6.1.1 Differential Omega Location Accuracy

The accuracy of fix using hyperbolic radio navigation systems, including Differential Omega, is a function of the accuracy in the measurement of the hyperbolic lines of position (LOP) and the crossing angles. The accuracy of the LOP's for Differential Omega is influenced by skywave contamination and varies from daylight to nighttime hours as well as seasonally throughout the year. Table 6-1 presents the 1σ errors in LOP

for day time and night time coverage.

For comparative purposes, conventional Omega errors are also shown in the table.

TABLE 6-1 DIFFERENTIAL OMEGA AND OMEGA LINE-OF-POSITION ACCURACIES (1σ)

	DAY	NIGHT
Differential Omega	0.25 n.m.	0.5 n.m.
Omega	1 n.m.	2 n.m.

In the New York Bight area, the crossing angles of Omega are on the order of 64.5 degrees with minor variations (approximately $\pm 1^{\circ}$) at ranges from 0 to 100 n.m. from Ambrose Light. The 95% probability fix can be computed directly from equation A7 of Appendix A assuming that the LOP errors are correlated by a factor, $K_{12} = 1/2$. Table 6-2 summarizes the 95% probability circular error for both the Differential Omega and conventional Omega systems using the above data and is applicable for both the 10 n.m. and 100 n.m. ranges.

TABLE 6-2 DIFFERENTIAL OMEGA AND OMEGA 95% RADIAL ERROR

	Day	Night
Differential Omega	.69 n.m.	1.39 n.m.
Omega	2.77 n.m.	5.55 n.m.

The circular error probabilities for 1/4, 1/2, 1, and 5 n.m. location accuracies for the specified 1σ LOP errors were calculated in accordance with the procedure outlined in appendix A1 and A2. A summary of results are given in Table 6-3.

TABLE 6-3 PROBABILITY OF VESSEL LOCATION ERROR USING OMEGA

Maximum Radial Error	Differential Omega Day	Differential Omega Night	Omega Day	Omega Night
0.25 n.m.	40%	13.4%	3.7%	1.1%
0.5 n.m.	81%	40%	13.4%	3.7%
1.0 n.m.	99%	81%	40%	40%
5.0 n.m.	100%	100%	99.9%	90%

6.1.2 LORAN C LOCATION ACCURACY

The accuracy of Loran C hyperbolic lines of constant time difference is typically on the order of 0.1 microsecond during daylight hours in this area with secondary phase corrections. Nighttime coverage increases the LOP error to 0.17 microseconds. In the New York Bight area, the most usable Loran C chain (Blue-Green) are Dana Air Force Base and Nantucket (Slaves) and Cape Fear, North Carolina (Master Station). At a 100 n.m. circle from Ambrose Light, the crossing angles are reasonably constant at approximately 80 degrees. To determine the vessel location accuracy in nautical miles, the LOP time difference line errors must be converted to distance error in nautical miles at the vessel location. Table 6-4 presents a summary of the computational results in determining the 95% circular probably error as a function of angular position on the 100 n.m. circle assuming equal LOP time difference errors of 0.1 μsec and a correlation factor of 1/2. The radial accuracy for 95% probability was determined as described in Appendix A-2.

TABLE 6-4 LORAN C 95% RADIAL ERROR FOR DAYTIME OPERATION AT 100 n.m. RANGE

True Bearing	Crossing Angle (deg.)	Green Line Spacing in n.m.	Blue Line Spacing in n.m.	LOP 1σ Error in N.M. for 0.1 μ sec. Green	Blue	95% Radial Error in n.m.
75°	89	18.8	7	.0183	.0085	.039
90°	77	18	16.7	.018	.0084	.039
105°	68.5	18	16.7	.018	.0084	.04
120°	65.5	17.7	15.7	.0177	.0079	.04
135°	63.5	17.5	15.7	.0175	.0079	.040
150°	64	16.2	16	.0162	.0008	.040
165°	65	15.8	16	.0158	.008	.039
180°	65.5	15.1	16	.0152	.008	.034

Night-time accuracy at 100 n.m. can be determined by multiplying the 95% Radial Error figures given in Table 6-4 by the ratio $\frac{(0.17)}{0.1} = 1.7$. At the 10 n.m. circular range from Ambrose Light, the 95% radial error is 0.035 n.m. for daylight operation and 0.06 n.m. for night-time coverage at any point along the 10 n.m. circle. It is apparent that the probable Loran C errors are less than 0.25 n.m. 100% of the time.

6.1.3 LORAN A LOCATION ACCURACY

Line-of-Position accuracies for Loran A are, in general, an order of magnitude worse than Loran C. For daytime coverage, the 1σ LOP time difference error is approximately 1 μsec and for night time coverage may increase an additional microsecond. The crossing angle of Loran A in the N.Y. Bight is somewhat worse than Loran C varying between 30 to 70 degrees depending on the vessel location within the 100 n.m. range from Ambrose Light. Table 6-5 summarizes the 95% probability value of radial error for the above 1σ LOP time difference errors for both 10 n.m. and 100 n.m. range circles from Ambrose at selected angular locations along the circles.

TABLE 6-5 LORAN-A 95% RADIAL ERROR FOR DAYTIME AND NIGHTTIME OPERATION AT 10 AND 100 N.M. RANGES

	10 N.M. RANGE CIRCLE			100 N.M. RANGE CIRCLE		
True Bearing	Crossing Angle (Degrees)	Radial Error in nm: Daytime	Radial Error in nm: Night Time	Crossing Angle (Degrees)	Radial Error in nm: Day Time	Radial Error in nm: Night Time
75°	32	0.36	0.72	23.5	0.45	0.90
90°	32	0.33	0.66	28	0.39	0.78
105°	40	0.31	0.62	34	0.34	0.68
120°	44	0.29	0.58	40.5	0.33	0.66
135°	48.3	0.28	0.56	49	0.32	0.64
150°	52.5	0.27	0.54	56.2	0.33	0.66
165°	58	0.26	0.52	67	0.35	0.70
180°	62	0.25	0.50	-	-	0.70

For 1/4, 1/2, 1 and 5 nm vessel locating accuracies, the percent probabilities of fix for the assumed 1σ LOP errors for Loran-A were calculated in a manner similarly used for Omega. A summary of the results is presented in Table 6-6.

TABLE 6-6 PROBABILITY OF VESSEL LOCATION ERROR USING LORAN A*

Maximum Radial Error	Day Time Operation	Night Time Operation
0.25 n.m.	89%	52%
0.50 n.m.	99.9%	90%
1.0 n.m.	100%	99.9%
5.0 n.m.	100%	100%

*Applicable for both 10 n.m. and 100 n.m. ranges.

6.1.4 SHORE BASED RDF LOCATION ACCURACY

The accuracy of fix using two shore based Radio Direction Finder stations depends on the range from the shore stations to the vessel, the geometric location of the RDF stations and the accuracy to which each RDF station can measure bearing. The bearing accuracy of a calibrated RDF instrument after suitable corrections generally does not exceed ± 1° with corrections. Additional errors arise, however, due to phase interference effects, polarization errors, lateral deviation due to ionospheric layer tilt, and site irregularities. In modern RDF systems, total bearing error generally does not exceed 2° and therefore the 1 standard deviation in bearing may be assumed to be on the order of 1°.

Using the approach outlined in Appendix A-1 and the results tabulated in Table A-1, vessel location accuracy at 10 mile and 100 mile ranges were computed at 15° increments along the range circles (0° corresponds to the true N-S line from Ambrose Light) assuming one RDF station located at Fire Island CG Station, L.I. and the other at Belmar CG Station in New Jersey. A summary of the radial error in nautical miles is given in Table 6-7.

TABLE 6-7 95% PROBABILITY RADIAL ERROR FOR FIX LOCATION SUBSYSTEM

True Bearing	Radial Error 10 n.m. Range	Radial Error 100 n.m. Range
90°	4.4	14.5
105°	2.4	12.8
120°	2.1	13.2
135°	1.7	14.1
150°	1.6	13.7
165°	1.7	12.8

Table 6-8 presents the percent probabilities for 1/4, 1/2, 1 and 5 n.m. maximum radial errors at the 10 and 100 n.m. ranges.

TABLE 6-8 PROBABILITY OF VESSEL LOCATION ERROR USING RDF

Maximum Radial Error	% Probability For 10 n.m. Range	% Probability For 100 n.m. Range
0.25 n.m.	25	2
0.5 n.m.	60	5
1 n.m.	95	10
5 n.m.	100	60

6.1.5 Shore Based Radar Location Accuracy

The accuracy of fix using a shore based radar and vessel beacon is a function of azimuth beam width, and pulse duration and timing jitter. Bearing accuracy is typically on the order of 1/4 or 1/5 of the azimuth beam width, which in turn is related to wave length and antenna azimuth

aperture. For an X-band radar, the azimuth beam width varies from 3^o for a 30" radar antenna to 5^o for an 18" antenna. For this study, an azimuth beam width of 3^o is assumed so that the 1σ bearing accuracy is under 1 degree. Range accuracy, assuming a pulse duration of 2 μ sec., is on the order of 1,000 feet, 1σ. With these bearing and range accuracies, vessel location accuracy is determined following the approach outlined in Appendix A-3. It is assumed the shore based radar is located at Ambrose light at an assumed antenna height of 100 feet and the vessel beacon height is 25 feet. For these conditions, the maximum operating range is approximately 18 n.m. Long range surveillance of dumping vessels is not feasible, even for a radar atop the tall World Trade Center (1,225 ft.); the maximum range is only about 42 n.m.

The 95% Probability Radial error for a 10 n.m. range from Ambrose light is computed to be 0.4 n.m.

Table 6-9 shows the percent probability corresponding to 1/4, 1/2, 1 and 5 n.m. maximum radial errors at 10 n.m. and 100 n.m. ranges.

TABLE 6-9 PROBABILITY OF VESSEL LOCATION USING RADAR

Maximum Radial Error	% Probability for 10 n.m. Range	% Probability for 100 n.m. Range
1/4 n.m.	62.5	0
1/2 n.m.	98.7	0
1 n.m.	100	0
5 n.m.	100	0

6.2 PROBABILITY OF DUMP DETECTION

Techniques for sensing the occurrence of a dump for the selected DMS candidates are as follows:

- Draft Sensing Unit
- Events Unit
- Actuator Switches
- Door/Valve Sensors

The draft sensing unit provides output signals in steps proportional to vessel draft as measured by pre-set pressure switches. Each pressure switch may be connected directly to the digital recorder to provide a print-out on one channel or may be connected to a resistor bank to provide a stepped current for an analog recorder. The events units contains manual switches which would be activated by the vessel captain for special events such as "dumping started" and "dumping completed". While this unit is not a direct measurement of the occurrence of a dump, when used in conjunction with recorded time and vessel location, and then certified by the captain, it provides a reasonable approach to ascertain proper dumping. The actuator switches are those switches used to activate solenoids, etc., to start the dump. Their status could be sensed in any of many ways. The door/valve sensors are envisioned as magnetic type switches which are operated by opening of the pocket doors on dump scows, gate valves or other dump devices so that they sense the release of dump. With the exception of the events unit, all of the above dump sensors might require custom installations on the dump vessels.

The MTBF and corresponding failure rates and reliabilities for the various dump sensors considered in the study are shown in the following table.

TABLE 6-10 RELIABILITY AND FAILURE RATES OF DUMP SENSORS

Sensor	MTBF (HRS)	Failure Rate	Reliability 6 Hr. Mission	36 Hour Mission
Draft Sensor	9,525	.000105	.99937	.99623
Events Unit Switch	125,000	.000008	.99996	.99975
Actuator Switch	100,000	.00001	.99994	.99964
Door/Valve Sensor	100,000	.00001	.99994	.99964

The probability of dump detection required for the performance effectiveness analysis discussed in Section 10.2 is based on the single sensor probability of detection and a worth factor which reflects the probability of any one of the approaches making a positive dump identification. Thus, the events unit switch would have a lower worth factor than the other sensors since it is not a positive indication of dump. In the subsequent discussion, Worth Factors of 0.95, 0.55, 0.80 and 0.80, respectively, were assumed for the Draft Sensor, the Events Unit, the Actuator Switch and the Door/Valve sensor.

The probability of dump detection is calculated using the equation for parallel redundancy. Thus,

(6-1) $P_{DD} = 1 - (1-K_1P_1)(1-K_2P_2)(1-K_3P_3)\ldots(1-K_iP_i)$, where

Ki is the worth factor associated with the individual sensor probability of detection, Pi. Table 6-11 summarizes the probability of dump detection for various combinations of dump sensors for both the 6-hour and 36-hour dump missions calculated using equation (6-1).

TABLE 6-11 PROBABILITY OF DUMP DETECTION, PDD

Dump Subsystem	PDD for 6 Hr. Mission	PDD for 36 Hr. Mission
Draft Sensor, DR	.94940	.94642
Events Unit Switch, EU	.54997	.54986
Actuator Switches, A	.79995	.79971
Door/Valve Sensors, D/V	.79995	.79971
EU + DR	.97723	.97218
EU + A	.90997	.90984
EU + D/V	.90997	.90984
DR + A	.98988	.98927
DR + D/V	.98988	.98927
A + D/V	.95998	.95988
EU + DR + A	.99544	.99443
EU + DR + D/V	.99544	.99443
A + DR + D/V	.99798	.99785
A + DR + D/V + EU	.99909	.99888

6.3 RECORDING

Monitoring of vessel location and the occurrence of dump as previously indicated may be performed either aboard the vessel using a digital printer, punched paper tape or magnetic tape or by a telemetry link to a shore processing center with suitable equipment for data processing, assimilation, and recording/storage. In the case of system candidates utilizing a shore based vessel locating subsystem, it is desirable to telemeter dump detection signals and other vessel information to the shore center for correlation with the vessel location measurements obtained at shore thereby providing real-time ocean dumping surveillance. System candidates 2, 3, and 4 are examples of the real-time monitoring and surveillance system approach.

However, this approach generally involves complex and costly equipments. Vessel on-board recording, although simpler and less costly, is limited to post-occurrence surveillance and requires the captain, upon return from a dump mission, to remove the recorded data and either via courier or mail send it to a processing center. Determination of the probability of obtaining a good recording of data therefore depends on the approach used for each candidate. Further, for system candidates utilizing dump sensors aboard a towed barge, with an additional recorder, the reliability of the recorder must be factored in the probability figure.

The probability of obtaining a good recording of data for the selected system candidates is based on the equation

(6-2) $$P_R = (R_T)\ (Pos)$$

Where R_T is the reliability of the data transmission and recorder subsystem during the dump missions, and Pos is the probability that the data transmission and recorder sybsystem is functionally operating.

The reliability estimates for the transmission and recorder subsystems (R_T) utilized by the system candidates were based on the equipment failure rates and were computed using an assumed exponential failure distribution. Both the 6-hour (10 n.m. range) and 36-hour (100 n.m. range) dump mission times were considered.

The probability that the subsystem is functionally operating (Pos) involves several considerations. In the case of a long-range telemetry link from the vessel to the shore, electrical disturbances caused by lightning during thunderstorms at times would cause the link to be unreliable. Reliability of data link transmission is dependent on the time of day, weather conditions, season, geographic location, and data link frequency. In the New York Bight area, the mean number of days for thunderstorm activity is 18 (Ref. Table B-1 of Bibliography). If it is assumed that the thunderstorm in the vicinity of the New York Bight lasts even for an 8 hour time period during which time noise prevents reliable data transmission to shore, then Pos = 0.98, which has only a small impact.

For the system candidates utilizing on-board recording, the probability of successful monitoring depends on the data being received by N.Y.D.C.E. If the courier or the Post Office loses the recorded data, monitoring is not considered successful. It will be assumed that lost data will occur no more than one time in 1,000 for which Pos = 0.999.

In candidate systems involving a telephone link from remote shore stations to a central processing center, the probability that the link is functionally operating is estimated to be at least 0.9999.

Table 6-12 presents the estimated values of the probability of transmission and monitoring for the system candidates using equation (6-2).

TABLE 6-12 PROBABILITY OF OBTAINING A GOOD RECORDING OF DATA, P_R

System Candidate	Reliability, R_T 6 Hr. Mission	36 Hr. Mission	Probability of Functional Operation, P_{OC}	Probability of Recording, P_R 6 Hr. Mission	36 Hr. Mission
1A	.991	.947	0.999	.991	.947
1B	.991	.947	0.999	.991	.947
1C	.994	.964	0.999	.994	.964
2	.964	.787	0.93	.945	.772
3	.931	.885	0.93	.962	.863
4	.982	.889	0.98	.963	.871

SECTION 7.0

RELIABILITY ANALYSIS

7.1 GENERAL

Reliability is an important consideration in the evaluation of candidate systems for the Dump Monitoring System. A system which may have excellent performance capability and rank high in legal effectiveness is of little value if its reliability is poor. The consequence of low system reliability are:

- High incidence of no data or unuseful data
- High maintenance costs
- Requirements for Large Number of Spares
- Possible damage of other shipboard equipments caused during removal/replacement of repaired units.
- Low system availability for Ocean Dump Monitoring
- Interruptions and Delays of Fleet Dumping Operations
- Less than desired true control over ocean dumping practices.

Sections 7.2 and 7.3 which follow provides an assessment of the reliability of the selected candidates for the DMS. The equipment reliability figures obtained in section 7.2 are used in section 7.3 to determine the overall system reliability of each candidate system.

7.2 EQUIPMENT RELIABILITY

Table 7-1 presents a listing of equipments and corresponding MTBF data for the selected system candidates. The MTBF data is based upon the most applicable and recent available information derived from field data, specification requirements, comparison to similar equipments and estimates based on parts count. To obtain

TABLE 7-1. EQUIPMENT MTBF DATA

Equipment	MTBF (Hrs.)
Loran A Receiver	1900
Loran C Receiver	1850
Omega Receiver	2000
Shore Based Radar	500
Vessel Radar Beacon	1000
Radio Direction Finder (Shore Based)	3000
RDF Transmitter	600
Ship to Shore Data Link	
• Vessel Transmitter	630
• Shore Receiver	1000
Barge to Towing Vessel Data Link	
• Transmitter	3500
• Receiver	5800
Digital Tape Printer	1000
Events Unit	10,000
Draft Sensor	9500
Dump Actuator Sensor	100,000
Valve/Door Sensor	100,000
Antenna Coupler	17,700
Computer	2000
PPI Display	750
Camera System	500
I/O Multiplexer	5000
Line Printer	1500
Barge Recorder	2180

meaningful data and to place all equipments on the same relative basis, experts within SSMO were consulted in their specialties and the information obtained was consolidated and normalized by a relaibility technical specialist. In this regard, the equipments and components considered for the DMS candidates will not be subjected to the stringent reliability assurance programs typical of government defense system equipments and it may be anticipated that commercial equipments and components contemplated for the DMS will have somewhat lower MTBF values. This aspect was taken into consideration in the MTBF figures shown in Table 7-1.

7.3 SYSTEM RELIABILITY

The estimate of system reliability for the DMS candidates is derived for both the short range (10 n.m. from Ambrose Light) and the long range (100 n.m.) dump missions. The corresponding mission times (round trip) for the above ranges is assumed to be 6 hours and 36 hours, respectively. Since several of the system candidates involve both shore based and vessel on board equipments, the reliability estimate takes into consideration differences in environmental conditions as well as equipment redundancy on shore installations. In addition, system candidates utilizing monitoring equipments aboard the barge will require separate reliability estimates for the self-propelled dump vessel and the towed barges. The reliability estimates were based on the exponential failure distribution (constant failure rate) given by:

(7-1) $$R = e^{-ft}$$

where f = overall equipment failure rate and

t = mission time

Table 7-2 presents a summary of overall MTBF figures for the selected DMS candidates. Table 7-3 summarizes reliability estimates for the system candidates for both the 6 and 36 hour dump missions. The overall MTBF figures takes into account the parallel redundancy of dump sensors. In this case, the actuation and door/valve switches as well as the draft status are considered in parallel; the events unit is assumed to be in serial with other equipments. An equivalent approximate failure rate for the parallel equipments was derived which was then added to the other equipment failure rate values were used in conjunction with equation (7-1) to derive the reliability of the system candidates.

TABLE 7-2 MTBF FOR SELECTED CANDIDATES

System Candidate	MTBF
1A	420
1B	368
1B'	372
1C	453
2	122
3	128
4	158

TABLE 7-3 RELIABILITY OF SYSTEM CANDIDATES

System Candidate	Reliability Estimate: 6 Hour Mission – Towed Barge	Reliability Estimate: 6 Hour Mission – Self Propelled Vessel	Reliability Estimate: 36 Hour Mission – Towed Barge	Reliability Estimate: 36 Hour Mission – Self Propelled Vessel
1A Differential Omega with on-board Dump Sensors, Events Unit, and Digital Printer	.986	.989	.918	.933
1B Loran C with on-board Dump Sensors, Events Unit and Digital Printer.	.984	.986	.907	.923
1B' Same as 1B but Loran A	.985	.987	.908	.923
1C Loran A with on-board Digital Printer and Events Unit	.987	.987	.924	.924
2 Shore Based Radar with on-board radar beacon, and dump sensors	.951	.955	.745	.758
3 Shore based RDF stations with on-board transmitter and dump sensors	.954	.957	.755	.768
4 Differential Omega with on-board dump sensors and Data Link	.963	.965	.796	.809

SECTION 8.0

MAINTAINABILITY AND SUPPORT ANALYSIS

8.1 MAINTENANCE PHILOSOPHY

Life cycle support costs of a system is often a significant percentage of the system procurement costs. A system that is both quickly and easily maintainable requires fewer manhours of less skilled labor, at lower training costs, to keep it operating throughout its life cycle. Maintainability, therefore, is an important factor in planning the acquisition of a new system or equipment. One of the primary objectives in any acquisition program is to generate a maintenance philosophy which gives promise of achieving an optimum balance between logistic support complexity and potential life cycle costs. These factors are intimately related to the system equipments complexity, the operational requirements of the system and maintenance resources (maintenance personnel, maintenance training, facilities, test equipments and equipment spares). It is apparent that generation of a maintenance concept for a new system requires fundamental tradeoff decisions regarding equipment design requirements, logistic criteria, and cost factors. The equipment design requirements include the following considerations:

- Utilisation of automatic monitoring and fault isolation as an integral feature of the system design to reduce fault location time.
- Utilization of a module replacement concept of maintenance to reduce maintenance skill level requirements, and/or to reduce downtime.
- Adaptation of a non-maintainable repair policy for replacement modules to reduce intermediate and depot repairs.

- Application of functional redundancy to allow on-line maintenance of critical or high failure rate components to minimize system down-time for corrective maintenance.

Adoption of any of the above approaches must be carefully evaluated since potential detrimental side effects on various system effectiveness parameters and logistic factors could easily result. For example, the use of built-in automatic test equipment may impose more reliability and maintainability problems than it solves if it is not properly designed or is overly complex.

In considering a maintenance concept for the DMS, several significant factors related to present ocean dumping operations and dump vessel personnel should be highlighted.

- The number of crew members aboard the dump vessel are generally less than six and their technical training or skill levels are minimal.
- The dump vessels are typically small by comparison with U.S. Naval ships and virtually have no onboard test and repair facilities.
- Dump missions are generally less than one or two days in duration with a non-operative time period at dockside for loading of waste material.
- The DMS equipments would be owned and serviced by the District Corps of Engineers.
- The distances from the N.Y. District Corps of Engineers offices in lower Manhattan to loading piers and docks is typically less than 50 miles thereby minimizing problems of logistics.
- The DMS should not require major participation by the dump vessel crew or intervene in any way with their normal operational duties.

- The equipments to be considered for the DMS are required to be basically off-the-shelf with minimal design changes or modifications.

On the basis of the above considerations, the following maintenance concept for the DMS was established.

1. The DMS will not have extensive performance monitoring or fault isolation features. Where feasible, the equipments shall incorporate warning lights to signify gross malfunctions and equipment failures.
2. On-board maintenance or service of the DMS equipments by the dump vessel crew would not be permitted except for the possible replacement of electrical fuses and replenishment of the printer/recorder paper tapes.
3. Intermediate levels of servicing and maintenance of the DMS equipments shall be performed dockside by a District Corps of Engineers representative either upon notification of malfunction/failure by the dump vessel captain, or in accordance with a scheduled maintenance program.
4. The DMS shall employ a unit replacement level maintenance concept at dockside. Upon telephone notification of a unit failure or malfunction, a NYDCE service representative shall replace the malfunctioning unit with a spare and make necessary adjustments to assure proper operation of the new unit.
5. Faulty or malfunctioning units removed from the dump vessel by the NYDCE service representative shall be repaired either at a repair depot or at the equipment manufacturer plant and returned upon repair to stock inventory.

The above maintenance philosophy will provide a high availability level for the DMS coupled with a minimum life cycle maintenance cost.

8.2 MEAN CORRECTIVE MAINTENANCE TIME ($\bar{M}_{ct}$)

The mean corrective maintenance time is defined in this report as the average time beginning with the observation of an equipment malfunction by the serviceman and ending when the equipment (either replaced with a spare or repaired) is restored to a normal operating condition. The time includes the average time to identify and remove the faulty equipment from the vessel and replace it with a spare unit and to checkout the system. Logistics and administrative time for transporting the spare unit or module from a storage depot is also included. The $\bar{M}_{ct}$ for the system is computed using the equation

(8-1) $$\bar{M}_{ct} = \frac{\sum (M_{ct})\ (f)}{\sum (f)}$$

where M_{ct} is the average corrective maintenance time for each unit, and f is its failure rate for each unit

Estimated values of $\bar{M}_{ct}$ assuming off-line unit replacement maintenance is based on an assumed logistics/administrative time of 1 hour; estimated average time for removal of the faulty unit, replacement with a spare unit and system checkout varies from 0.2 to 1.0 hours. A summary of the mean corrective maintenance time for the selected system candidates is presented in Table 8-1. The operational availability of each system candidate can be computed from the equation (8-2).

(8-2) $$Ao = \frac{\overline{MTBF}}{\overline{MTBF} + \bar{M}_{ct}}$$

where $\overline{MTBF}$ is the overall system mean time between failure

TABLE 8-1 $\bar{M}_{ct}$ FOR SELECTED SYSTEM CANDIDATES

System Candidate	$\bar{M}_{ct}$
1A	3.5
1B	2.5
1B'	2.1
1C	2.0
2	3.7
3	2.1
4	3.8

8.3 MEAN TIME TO REPAIR (MTTR)

The Mean Time to Repair (MTTR) is the mean corrective maintenance time ($\bar{M}_{ct}$) plus the average time to isolate the fault to a replaceable assembly at the maintenance depot and less the logistics administration time (for transportation). The MTTR is a measure of system complexity and is utilized in the overall score rating criteria presented in Section 10. Table 8-2 summarizes the estimated MTTR for the system candidates based on available MTTR figures for similar types of equipments compiled by the U. S. Naval Applied Science Laboratory.

TABLE 8-2 MTTR FOR SELECTED CANDIDATES

System Candidate	MTTR, Hrs.
1A	2.5 to 4
1B	2 to 2.5
1B'	2 to 2.5
1C	1.5 to 2
2	2.5 to 4
3	2 to 2.5
4	2.5 to 4

SECTION 9.0

COMPARATIVE COSTS

9.1 DEFINITION OF THE TOTAL COST OF OWNERSHIP ELEMENTS

The Total Cost of Ownership (TCO) is comprised of the following cost elements.

- Acquisition costs for the DMS equipments.
- Spares Costs for Equipments and Replacement Modules
- Ship and Shore Based Stations Installation Costs
- Maintenance Costs
- Operational Costs

The acquisition costs include both vessel on-board equipments and shore based equipments acquisition costs. Systems engineering and design costs as well as start-up costs are included in the acquisition cost of the systems. Cost of spares for equipments and replaceable modules are based on equipment unit acquisition cost. The number of unit spares required for a system candidate is based on the number of units required for dock-side maintenance as well as the number of units in the pipeline for repair at the depot/maintenance facility.

Installation costs for both the ship and shore based facilities include the costs required for the preparation of an installation specification, detail installation drawings, checkout of installation preparation, installation of equipment and system checkout. The cost associated with ship preparation, such as providing a mounting surface on a dump door mechanism or a pipe connection for the draft sensor will be assumed to be

the responsibility of the dump vessel owner. The maintenance costs reflects corrective maintenance, shop and depot maintenance and scheduled maintenance costs. The operational cost is based solely on the number of N.Y.D.C.E. personnel required to operate and monitor the DMS.

For the cost effectiveness analysis, life cycle costs for the system candidates are based on a 50 dump vessel DMS buy operating for a 5 year period assuming 2,000 operating hours per year. The computational procedure for estimating the life cycle cost based on the above defined TCO elements, is described in the following section. Details and rationale used in developing the TCO for the system candidates is presented in Section 9.3. Charts in this section show dollars for a 50 vessel DMS buy.

9.2 TCO METHOD

The method used in estimating the TCO is outlined below and includes all of the TCO elements described in Section 9.1.

(9-1) TCO = Acquisition Costs + Spares Cost + Installation Costs + Maintenance Costs + Operational Costs

The spares cost is taken as the sum of the equipment spares cost and the replaceable module spares cost. The equipment spares cost is based on the equipment unit acquisition cost times the number of spares estimated at 20% of the acquired units for both pipeline repair and dockside maintenance. The replaceable module spares cost was taken as 10% of the equipment spares cost and was considered only for certain system equipments such as receivers and transmitters. Ship installation costs are based on the estimated number of weeks required to prepare installation specifications, prepare detail drawings, checkout installation preparation, install equipments and

checkout system for 50 vessels multiplied by applicable personnel weekly salary.

$$\text{Installation Cost} = \left(\frac{\text{Installation Time in Weeks}}{\text{Dump Vessel}}\right) \times (\text{No. of Vessels}) \times \left(\frac{\text{Cost}}{\text{Week}}\right)$$

Installation costs for shore facilities was estimated based on figures presented in references 2 and 3 of the bibliography. The Maintenance Costs for the system candidates was taken as 4%/year of the initial acquisition costs. Over a 5 year life cycle, this figure results in a maintenance cost of 20% of the initial acquisition costs. Field service costs for all candidates was assumed identical and therefore was not considered for the TCO analysis. A more rigorous approach at estimating maintenance costs would have utilized the maintenance man hours per operating hour $\frac{\text{MMH}}{\text{OH}}$ considering both scheduled and unscheduled maintenance. Realistic figures of MMH/OH for the system candidate equipments were not available, however, and the above approach was considered to be a realistic estimate of the maintenance costs for systems of the complexity considered. Operational Cost is estimated on the basis of the number of personnel man years required to operate the DMS for 24 hour day coverage for a 5 year life cycle. Thus,

$$\text{Operational Cost} = \left(\frac{\text{Man Years}}{\text{Year}}\right) \times (5\text{ Yrs.}) \times \left(\frac{\text{Salary}}{\text{Yr}}\right)$$

9.3 TCO ESTIMATES FOR CANDIDATE SYSTEMS

9.3.1 Acquisition Cost for Candidate Systems

The acquisition costs for the candidate systems were based on estimated costs for each equipment comprising the candidate system equipment suit as well as system engineering and start-up costs. Estimated equipment costs were derived from new quotations obtained from equipment manufacturers, past quotes on identical or similar equipments available at SSMD and estimates obtained from SSMD personnel knowledgeable in the equipment area of concern. Table 9-1 summarizes the estimated on-board and shore facility acquisition costs for the candidate systems.

TABLE 9-1 ACQUISITION COSTS FOR CANDIDATE SYSTEMS

	Candidate System					
	1A	1B/1B'	1C	2	3	4
On-Board Equipments	863,000	802,000	569,000	1,041,000	821,000	1,260,00
Shore Equipments	44,000	----	----	815,000	402,000	155,0
Total Acquisition Costs	907,000	802,000	569,000	1,856,000	1,223,000	1,415,00

9.3.2 Spares Cost for Candidate Systems

The estimated number of equipment and replaceable module spares for each candidate system for a 5 year life cycle was based on a figure of 10% of the system operational units required for dockside maintenance and 10% for units in the pipeline for rework. The spares cost was determined from these estimates and the results summarized in the following table.

TABLE 9-3 SPARES COST FOR CANDIDATE SYSTEMS

	Candidate System					
	1A	1B/1B'	1C	2	3	4
Module Spares	7,000	5,000	4,500	100,000	10,000	16,000
Unit Spares	107,000	99,000	64,500	141,000	140,000	188,000
Total Spare Costs	114,000	104,000	69,000	241,000	150,000	204,000

9.3.3 Installation Costs for Candidate Systems

Table 9-4 summarizes ship and shore facility installation costs for the candidate systems. The ship installation costs were based on estimated manpower requirements for installation of the DMS aboard 50 vessels assuming an engineering burden of $800/week. Shore facility installation costs for candidates 2, 3, and 4 were estimated on the basis of information presented in references 2 and 3 of the bibliography.

TABLE 9-4 INSTALLATION COSTS

	Candidate System					
	1A	1B/1B'	1C	2	3	4
Ship Install. Costs	104,000	104,000	50,000	104,000	104,000	104,000
Shore Install. Costs	----	----	----	500,000	350,000	50,000
Total	104,000	104,000	50,000	604,000	454,000	154,000

9.3.4 Maintenance Costs for Candidate Systems

Table 9-5 summarizes estimate maintenance costs for the system candidates based upon the 4%/year of the acquisition cost figure assumed applicable for the DMS, excluding start-up costs.

TABLE 9-5 MAINTENANCE COSTS FOR CANDIDATE SYSTEMS

	Candidate System					
	1A	1B/1B'	1C	2	3	4
Maintenance Cost	156,000	140,000	94,000	320,000	262,000	290,000

9.3.5 Operational Costs for Candidate Systems

Estimated operational costs based on the number of personnel required to operate each system candidate for a 5 year life cycle are summarized in Table 9-6 (assume an operating personnel salary of $15,000/yr.).

TABLE 9-6 OPERATIONAL COSTS FOR CANDIDATE SYSTEMS

	Candidate System					
	1A	1B/1B'	1C	2	3	4
Operational Cost	75,000	75,000	75,000	225,000	435,000 + Telephone Link	225,000

9.4 COMPARATIVE COST SUMMARY

A summary of the total cost of ownership for the system candidates based upon the results contained in Section 9.3 is given in Table 9-7. Candidate system 1C is shown to have the lowest TCO whereas candidate 2 has the greatest TCO. The comparatively large TCO for candidate system 2 results from the high acquisition and installation costs for a shore based radar station. This is also the case for system candidate 3. Candidates 1A and 1B are comparable in cost differing essentially in the running costs of the Omega and Loran C receivers. The low TCO for system candidate 1C is due to the minimal on-board equipments utilized resulting from the approach of omitting any sensors or equipments aboard the towed barge. The TCO for candidate 1B' is, as shown, approximately equal to candidate 1B.

TABLE 9-7 TOTAL COST OF OWNERSHIP FOR CANDIDATE SYSTEMS

	Candidate System					
	1A	1B/1B'	1C	2	3	4
Acquisition	907,000	802,000	569,000	1,856,000	1,223,000	1,415,000
Spares	114,000	104,000	69,000	241,000	150,000	204,000
Installation	104,000	104,000	50,000	604,000	454,000	154,000
Maintenance	156,000	140,000	94,000	320,000	262,000	290,000
Operating	75,000	75,000	75,000	225,000	435,000	225,000
Total TCO in Dollars	1,356,000	1,225,000	857,000	3,246,000	2,524,000	2,289,000

SECTION 10.0

RATING OF CANDIDATE SYSTEMS

10.1 EVALUATION OF EMS CANDIDATES

The evaluation of the selected EMS candidates is based on the overall score ratings developed from criteria presented in Section 5.0. This criteria utilizes weighted ratings of significant EMS parameters (subscores) which are combined to reflect an overall candidate score. The significant parameters to be evaluated, with assigned weightings and ratings follow discussions of Section 5.0; values are developed in Sections 6.0, 7.0, 8.0, and 9.0. The following paragraphs present the computations and rationale used in determining the overall score of the EMS candidates. Paragraph 10.2 contains the performance effectiveness of the candidate systems which is utilized in Section 10.3 to derive the relative cost effectiveness of the EMS candidates. Section 10.4 presents the pertinent factors and computations leading to the establishment of the parameter subscores and the overall score ratings for the EMS candidates summarized in paragraph 10.5.

10.2 PERFORMANCE EFFECTIVENESS

The performance effectiveness of the system candidates defined as the weighted relative value of the candidate EMS in accomplishing the defined mission (V_{EMS}) was determined using the method discussed in paragraph 5.1.6 and summarized by the equation

$$(10\text{-}1) \quad V_{EMS} = \frac{W_{DD} P_{DD} + W_L P_L + W_R P_R + W_{RR} P_{RR} + W_S P_S}{W_{DD} + W_L + W_R + W_{RR} + W_S}$$

where,

V_{DMS}	=	weighted relative value of performance effectiveness a candidate
P_{DD}	=	probability of detecting the occurrence of a dump
P_L	=	probability of locating vessel to within specified accuracy
P_R	=	probability of correct recording of dump information
P_{DR}	=	probability of identifying an improper dump during manual data review
P_E	=	probability of effective utilization of data
W_{DD}	=	Dump detection subsystem worth = 2
W_L	=	Vessel location subsystem worth = 4
W_R	=	Recording subsystem worth = 4
W_{DR}	=	Data Review worth = 1
W_E	=	Effectivity worth = 1

Each of the above probability terms for the selected candidates was estimated from applicable data contained in Sections 6.0 and 7.0.

10.2.1 Probability of Detecting Dump

In Section 6.2, the probability of detecting the occurrence of dump for various dump sensors and combinations thereof were computed and summarized. As shown in Table 6-9, the dump detection probability depends on the type and number of dump detection sensors utilized for the candidate being evaluated. With the exception of candidate 1C, all candidates utilize the same four methods for sensing dump detection considered applicable for the DMS, namely: draft sensor, events unit, and, where applicable, door/valve status sensors. For candidates 1A, 1B, 1B', 2, 3, and 4 therefore,

the probability of dump detection based on the results given in Table 6-9 is approximately 0.9993 for both the 6 and 36 hour dump missions. Candidate 1C, which utilizes only an events unit, has a lower detection probability estimated to be 0.5499 and 0.5498 for the 6 hour and 36 hour dump missions, respectively.

10.2.2 Probability of Vessel Location Accuracy

The probability of locating the dump vessel to within a specified accuracy (P_L) depends on the accuracy of the vessel location subsystem used, its reliability during the dump mission and its operational state throughout the mission. Thus,

(10-2) $P_L = P_{VL} \times P_R \times Pos$ where,

P_{VL} = probability of the locating subsystem yielding the specified accuracy

P_R = probability of the location system being reliable throughout the mission and

Pos = probability of the location subsystem being operational.

To clarify the difference between P_R and Pos, the first probability reflects the probability of an equipment failure during the mission whereas the latter reflects operational capability of the equipment in disturbing environments such as weather or proximity to steel structures and buildings. Thus, a system although functioning properly may not be capable of providing location measurements throughout the mission due to various disturbing influences. As a further example, a captain could often claim lack of ability to use Loran C (but not Loran A) and thus Pos for Loran C must be given a lower rating.

In Section 6.1, the performance accuracies of the various system candidates were determined. As part of this analysis, the probability of locating the vessel to within 0.5 n.m. and 5 n.m. corresponding to the short and long range dump mission accuracies specified were computed for the selected system candidates. A summary of these results are presented in Table 10-1. The P_R and Pos for the system candidates also included in this table were determined as follows:

The probability of the vessel locating subsystems being reliable (P_R) for the 6 and 36 hour dump missions was determined for each candidate based on the equipment failure rates presented in Table 7-1. The operational status probability was estimated based on the weather data presented in Appendix B and, as applicable, on estimates of approximate percentage of time where bridges, strong radio signals and other r-f interferences causes a limitation. The overall probability of locating dump vessels to within the specified accuracy requirements for the candidate systems was computed using equation 10-2 based on the P_{VL}, P_R, and Pos probability figures shown in Table 10-1.

TABLE 10-1 SUMMARY OF VESSEL LOCATION ACCURACY PROBABILITIES FOR SYSTEM CANDIDATES

System Candidate	P_{VL} A	P_{VL} B	P_R A	P_R B	P_{os} A	P_{os} B	P_L A	P_L B
1A	.81	1.0	.995	.973	.99	.99	.798	.964
1B	1.0	1.0	.994	.961	.75	.80	.745	.768
1B'	.999	1.0	.994	.961	.90	.96	.894	.922
1C	.999	1.0	.994	.962	.90	.96	.894	.923
2	.987	-0-	.966	.795	.90	-0-	.856	-0-
3	.625	.600	.977	.859	.95	0.85	.587	.437
4	.81	1.0	.995	.973	.95	.85	.766	.827

NOTE: Gen1 - A is for 10 n.m. from Ambrose: B is for 100 n.m. from Ambrose.

10.2.3 Probability of Successful Data Recording

The probability of successful data transmission and recording for the system candidates was estimated in Section 6.3 for both the 6 and 36 hour dump missions. The results are summarized in Table 10-2.

TABLE 10-2 PROBABILITY OF SUCCESSFUL DATA RECORDING

System Candidate	P_R 6 Hr.	P_R 36 Hr.
1A	.991	.947
1B	.991	.947
1B'	.991	.947
1C	.994	.964
2	.945	.772
3	.962	.868
4	.963	.871

10.2.4 Probability of Successful Data Review

The probability of identifying an improper dump during a normal data review is assumed to be 1 for system candidates utilizing a digital computer for data processing and 0.995 for system candidates utilizing manual processing but using good data formats. The rationale for these estimates is as follows. With a digital computer, properly programmed, functioning and debugged, the probability of incorrect processing would be highly unlikely and could arise perhaps from some obscure program routine which for a peculiar set of data would give incorrect computation. Situations of this type occur so infrequently as to be considered unlikely and therefore P_{DR} is assumed unity. In manual processing, human errors at times do occur and it is conceivable that an ocean dumping offender would not be detected due to incorrect reading of recorded data. In lieu of applicable data which would provide an estimate of the number of times an error would occur, it was assumed that for every 1,000 cases reviewed, an error resulting on an undetected violator would occur only five (5) times.

10.2.5 Probability of Effectivity of Data Utilization

For the performance effectiveness study, it was assumed that system candidates which utilize captain certification of recorded data have a probability of effective utilization of the data, P_E, of 0.998. All of the other candidate systems are assumed to have a $P_E = 0.95$.

10.2.6 Performance Effectiveness Summary for System Candidates

The relative value of performance effectiveness for each candidate, as defined by V_{DMS} was computed using equation (10-1) based on the results presented in Paragraphs 10.2.1 through 10.2.4. Table 10-3 summarises the results for the selected system candidates for both the short range and long range dump missions. As shown in the table, system candidate 1B' (Loran A with dump sensors and printer) followed closely by candidate 1A (Omega with dump sensors) has the highest relative value of a DMS candidate in accomplishing the short range mission. For the long range mission, candidate 1A (Differential Omega with On-board Dump Sensors) followed closely by candidate 1B' has the highest V_{DMS}. Candidate 2 has a low V_{DMS} for the long range mission because of the radar range limitation. Candidate system 4 has lower values of V_{DMS} than candidate 1B for both the short and long range mission due to the vessel-to-shore data link system which causes reduced system reliability.

TABLE 10-3 PERFORMANCE EFFECTIVENESS OF SYSTEM CANDIDATES

System Candidate	V_{DMS} - Relative Value of Performance Effectiveness Short Range (10 n.m.)	Long Range (100 n.m.)
1A	.929	.969
1B	.911	.904
1B'	.961	.956
1C	.887	.887
2	.929	.586
3	.845	.764
4	.905	.895

10.3 RELATIVE COST EFFECTIVENESS

The relative cost effectiveness of the system candidates was calculated, using equation (5-3), for the two dump missions, based on the performance effectiveness figures given in Paragraph 10.2 and the total cost of ownership estimates summarized in Table 9-7. Cost effectiveness results are summarized in Table 10-4.

TABLE 10-4 RELATIVE COST EFFECTIVENESS OF SYSTEM CANDIDATES

System Candidate	Relative Cost Effectiveness R.C.E. 10 n.m. Mission	100 n.m. Mission
1A	0.685	0.715
1B	0.744	0.738
1B'	0.784	0.780
1C	1.035	1.035
2	0.286	0.181
3	0.335	0.303
4	0.396	0.391

As shown in the table, candidate 1C has the highest relative cost effectiveness figure for both the 10 and 100 n.m. dump missions. This is due to the high relative performance effectiveness (V_{DMS}) coupled with the low TCO for this system. Candidate 1B', although having a somewhat higher value of V_{DMS} than 1C, is shown to have lower relative cost effectiveness resulting from the higher TCO associated with the on-board dump sensors. The poor ranking of candidates 2, 3, and 4 results primarily from the very high TCO associated with acquisition and installation costs for shore based equipments coupled with somewhat reduced relative performance effectiveness.

10.4 DISCUSSION OF RATING RESULTS

In the following paragraphs are presented the results of the ratings for each DMS candidate in accordance with the established rating criteria contained in Section 5.0. Overall score of the DMS candidates, based on the subscore ratings, is presented in Paragraph 10.4.11. The overall score provide. effective evaluation method for use in selecting the preferred DMS.

10.4.1 Range of Coverage Subscore (S1)

The usable range of Omega system is approximately 2,000 n.m. In the differential Omega l locating subsystem used in candidates 1A and 4, the shore based Omega receiver provides corrections to the skywave thereby resulting in improved accuracy. If, however, the shore receiver and the vessel on-board receiver are separated by large distances, then the differential Omega accuracy is considerably reduced. Significant degradation occurs beyond a range of 400 to 500 n.m. Thus, the ratings selected for both DMS candidates 1A and 4 are 1.1. Loran C range capability exceeds 1,000 n.m. with little degradation in accuracy. Thus, the rating for candidate 1C is also taken as 1.1. The range of Loran A used in candidates 1B and 1B' is on the order of several hundred miles depending on propagation path and time of day. Accuracy is somewhat reduced at long ranges and from a comparative evaluation of the DMS candidates, a rating of 1.0 was chosen. The shore based radar system approach used in candidate 2 has limited range capability due to line-of-sight considerations and degradation caused by precipitation. Considering possible

locations to provide maximum antenna heights, the line-of-sight range is on the order of 20 n.m. from Ambrose. Thus, the range of coverage rating for candidate2 was taken as 0.5. With the RDF vessel location subsystem used in candidate 3, the range of coverage depends on the vessel transmitter power and the operating frequency used. Assuming an operating frequency in the 2 to 3 MHz band and reasonable transmitting power (100 to 150W), a range of 100 n.m. is not uncommon. The rating for candidate 3 therefore was estimated to be 0.9. Ratings for R1, the range capability of the DMS candidates, are summarized below.

TABL [illegible] RANGE RATINGS

Candidate	Rating R1
1A	1.1
1B	1.1
1B'	1.0
1C	1.0
2	0.5
3	0.9
4	1.1

10.4.2 Legal Effectivity Subscore (R2)

The legal effectivity ratings for the selected candidates is subjective and, in accordance with the criteria set forth in Section 5.1.2, all of the DMS candidates will generally provide sufficient data which will hold up in court. Since it is anticipated somewhat greater legal effectiveness is derived with a system using on-board dump sensors, even though a strong court case is only implicit on the basis of vessel location,

recorded events, timing, and captain certification of recorded data, the rating assessment of candidate 1C was set somewhat less than the other candidates. Thus, the legal effectiveness ratings for the DMS candidates is as follows.

TABLE 10-6 LEGAL EFFECTIVITY RATINGS

Candidate	Rating R2
1A	1.0
1B	1.0
1B'	1.0
1C	0.8
2	1.0
3	1.0
4A	1.0

10.4.3 All-Weather Capability Subscore (S3)

The all-weather capability subscore provides an assessment of significant weather factors on the performance of the DMS candidate. Candidates 1A, 1B, 1B' and 1C all contain on-board vessel location (with very long time constants), and on-board recording subsystems, and thus are not significantly influenced by weather. At times, atmospheric disturbances would result in loss of tracking. The percentage of time this would occur is estimated to be less than 1%. With the shore based radar approach used in candidate 2, even moderate precipitation rates significantly reduces ranging capability of both the shore based radar and radar beacon. Based on the data presented in Appendix B, it is estimated that significant

degradation would result approximate 4% of the time and therefore the rating is taken as 0.8 for candidate 2. Candidates 3 and 4 which utilize a vessel to shore data link are susceptible to noise caused by atmospheric disturbances which at times prevents reliable transmission of data signals. However, it is estimated that unreliable transmission due to weather environments would occur approximately only 2% of the time, and thus, for candidate 3 and 4 a rating of 1.0 was selected. Ratings used in the S3 - All-Weather Capability-Subscore for the DMS candidates are summarized in Table 10-3.

TABLE 10-3 ALL-WEATHER RATINGS

Candidate	Rating R3
1A	1.1
1B	1.1
1B'	1.1
1C	1.1
2	0.8
3	1.0
4	1.0

10.4.4 Automaticity Subscore (S4)

The ratings considered for the automaticity subscore is a measure of the degree of participation by the vessel captain/crew required for proper DMS operation. In system candidates 1A, 1B', and 1C only minor participation is required and that with little difficulty for almost the entire dump mission. Therefore their ratings were chosen as 1.0 In candidate 1B, moderate difficulty is anticipated in the acquisition

of proper Loran C station signals by the vessel captain and therefore, a somewhat reduced rating (0.8) was used. For candidates 2, 3, and 4, essentially no participation by the vessel captain is required and therefore, a rating value of 1.1 was used. A summary of ratings for the DMS candidates used in the Automaticity Subscore follows.

TABLE 10-8 AUTOMATICITY RATINGS

Candidate	Rating R4
1A	1.0
1B	0.8
1B'	1.0
1C	1.0
2	1.1
3	1.1
4	1.1

10.4.5 Initial Cost Subscore (S5)

At a meeting with NYDCE, it was recommended that for the present study, a value of 1.0 be used for all system candidates, indicating that the overall score be relatively insensitive to initial cost.

10.4.6 Cost Effectiveness Subscore (S6)

The ratings for the cost effectiveness subscore were based on the relative cost effectiveness values calculated in Paragraph 10.3 and summarized in Table 10-4. A summary of ratings based on the tabulated results and the rating criteria presented in Paragraph 5.1.6 is as follows.

TABLE 10-9 COST EFFECTIVENESS RATINGS

Candidate	Rating R6
1A	0.9
1B	0.9
1B'	0.9
1C	1.0
2	0.5
3	0.5
4	0.5

10.4.7 Location Accuracy Subscore (S7)

Location accuracy ratings for the IMS candidates were based on the performance accuracies calculated in Section 6.0 using the rating criteria given in Paragraph 5.1.7. The following ratings were established.

TABLE 10-10 LOCATION ACCURACY RATINGS

Candidate	Rating R7
1A	0.9
1B	1.1
1B'	1.0
1C	1.0
2	1.0
3	.8
4	.9

10.4.8 Design Factors Subscore (S3)

The ratings for the Design Factors subscore is based on a weighted average of ratings established for reliability, maintainability, equipment weight and size, on-board DMS power requirements, DMS warm-up requirements and service environment capability. The table following summarizes the individual ratings for the above design factors and also shows the overall design factor ratings.

TABLE 10-11 DESIGN FACTORS RATING

System	Reliability	Maint.	Weight & Size	Pwr. Rqmts.	Warm-up Rqmts.	Service Environ.	Overall Design Factor Ratings
1A	0.9	0.8	1.1	1.0	1.1	1.1	0.93
1B	0.8	0.8	1.1	1.0	1.1	1.1	0.93
1B'	0.8	0.8	1.1	1.0	1.1	1.1	0.93
1C	1.0	0.9	1.1	1.0	1.1	1.1	0.99
2	0	0.6	1.1	1.0	1.1	1.0	0.55
3	0	0.8	1.1	1.0	1.0	1.0	0.61
4	0.6	0.6	1.1	1.0	1.1	1.1	0.89

As shown in the Table 10-11, the significant design factors which influence the DMS candidate rating are reliability and maintainability. The reliability rating criteria was established in terms of the overall system MTBF and, for candidates 2 and 3, are shown to be less than 150 hours. The somewhat higher reliability of candidate 1A over candidates 1B and 1B' reflects the use of the two Loran C and two Loran A receivers in these candidates. The high reliability value for candidate 1C is directly attributable to the elimination of the on-board deep detection subsystem. The maintainability ratings were based on the MTTR estimates contained in Section 8.0.

10.4.9 Miscellaneous Factors Subscore (S9)

The DMS candidate ratings for the Miscellaneous Factors Subscore were based on separate ratings for the following factors: safety; equipment interchangeability; installation flexibility; tamper-proof; growth capability in range, navigation aid capability, and accuracy; training; and deterrent value. Ratings for these factors along with overall rating values for the DMS candidates are contained in Table 10-12.

TABLE 10-12 - MISCELLANEOUS FACTORS RATING

SYSTEM	SAFETY	INTER-CHANG	INSTLN FLEXI-BILITY	TAMPER PROOF	GROWTH RANGE	GROWTH NAV AID	GROWTH ACCURACY	TRAIN-ING	DETER-RENT	OVERALL RATING, R_9
1A	1.0	1.0	0.9	1.0	1.1	1.1	1.1	1.0	1.0	1.0
1B	1.0	1.0	0.9	1.0	1.1	1.1	1.1	1.0	1.0	1.0
1B'	1.0	1.0	0.9	1.0	1.0	1.1	1.0	1.1	1.0	1.01
1C	1.0	1.1	1.1	1.0	1.0	1.1	1.0	1.1	0.8	1.03
2	1.0	1.0	1.0	1.0	0	0	0	1.1	1.1	.90
3	1.0	1.0	1.0	1.0	1.0	0	0	1.1	1.1	.94
4	1.0	1.0	0.9	1.0	1.1	1.1	1.1	1.0	1.1	1.05

10.4.10 Hardware Availability Subscore (S10)

With the exception of candidates 2 and 3, all DMS candidates are rated 1.0 for the S_{10} subscore. Candidate 2 which utilizes non-existing shore radars and vessel radar beacons, would require significant development and, accordingly, a rating of 0.5 was chosen. Candidate 3 requires considerably less development and a rating of 0.9 was assigned. Table 10-13 summarizes the results.

TABLE 10-13 HARDWARE AVAILABILITY RATINGS

SYSTEM	R_{10} RATING
1A	1.0
1B	1.0
1B'	1.0
1C	1.0
2	0.5
3	0.9
4	1.0

10.4.11 Overall Score of DMS Candidates

The overall score of the DMS candidates was computed using equation (5-1) from the subscore ratings contained in the preceding paragraphs and the assigned weightings given in section 5.0. A summary of the overall scores for the DMS candidates are shown in the following table:

TABLE 10-14 OVERALL SCORE OF DMS CANDIDATES

SYSTEM	OVERALL SCORE
1A	0.89
1B	0.87
1B'	0.91
1C	0.90
2	0.04
3	0.16
4A	0.44

As shown in Table 10-14, system candidate 1B' has the highest overall score followed closely by candidate 1C. It should be noted that candidate 1B' also had the highest relative value of performance effectiveness of the candidates whereas candidate 1C had the highest cost effectiveness due to its low TCO. It also should be noted that candidate 1B' differs from candidate 1C only in that positive dump sensing is included for candidate 1B'.

10.5 Summary of Evaluation

The evaluation results of the preceding sections have identified candidate 1B' (Loran A with Onboard Draft Sensing and Digital Printer) as the preferred system approach for the DMS. Since this candidate differs from candidate 1C only by the addition of positive dump sensing, it is desirable to consider candidate 1B' made up of the basic 1C system, Loran/Events/Printer System (LEPS), supplemented by a positive dump sensing subsystem. With this concept, maximum flexibility in the adaptation of the DMS candidate 1B' for various vessel types such as self-propelled or towed dump scows is provided. In the case of a towed dump scow, the LEPS would be provided on the towing tug and the dump sensor subsystem designated as SIDS (Scow Indicating Draft System) would be installed on the towed scow. For installations complete on one vessel, such as self-propelled dump vessels, the addition of the positive dump sensing to the basic LEPS is designated DELPS (Draft/Events/Loran/Printer System).

As shown by the evaluation results, LEPS in itself provides reasonable performance effectiveness and will be a useful portable system. DELPS, LEPS, and LEPS with SIDS all have the following additional noteworthy features:

- All are low cost systems which have a high probability of satisfying the objectives for the DMS,
- All provide a high probability of detecting violations and offer a strong deterrent capability,
- There is a high confidence in the designs because only off-the-shelf equipments and proven concepts are used,
- They are readily adaptable to all dump vessels with minimal vessel preparation and LEPS requires no signal transfer between a tug and a towed scow and,
- They represent a system approach which could become operational within 1 year.

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SECTION 11.0

RECOMMENDED PREFERRED SYSTEM

The previous sections discussed the systematic considerations leading to the selection of the Loran-Events-Printer-System (LEPS) plus positive dump sensing (candidate 1B') as the recommended preferred approach for monitoring ocean dumping in the New York Bight. This approach was rated only slightly superior to the basic system (LEPS), without the dump sensing (candidate 1C). The evaluation included examination of all known reasonable approaches. Although the basic system, LEPS, may be used by itself for many applications, there will be situations where positive sensing of the occurrence of dump by measuring vessel draft is deemed necessary or desirable. When the draft sensing is added to LEPS by installation aboard the same vessel, such as on self-propelled dumpers, the resulting system is called DELPS (for Draft-Events-Loran-Printer-System). When draft sensing is added to a towed scow, the basic system (LEPS) is used aboard the tug and the system aboard the towed scow is called SIDS (for Scow, Indicating-Draft System). In all three DMS configurations, provisions are made to accept and record status signals from monitoring of dump valves, scow doors, etc. However such status signals, if used, would be customized for each vessel. Although the systems are described in various other sections of this report, in this section a summary description of the key features of the system are presented.

11.1 ATTRACTIVE FEATURES

The preferred DMS in all three configurations has many particularly attractive features for this application, as described briefly below.

- All the electronics for LEPS are housed in a single "black-box" which requires electrical connections only to ships power,

ships ground, an antenna, and the draft sensing unit (where used). The sea water pressure connection to the Draft Sensing Unit (used for DEAPS and SIDS) can be made up ship side of an existing sea cock. This all results in a simple installation which requires neither drydocking nor costly vessel modification.

- LEPS offers a portability concept and requires minimal vessel preparation, so that it is practical for a system to be temporarily used aboard a vessel which only occasionally needs a DMB.
- No special ashore station is required, thus reducing cost and complications in operations.
- The system requires no exchange of signals between tug and towed dumper.
- The system provides a printed record of vessel position versus time and indicates start and end of dump as well as other key events (such as "passing Ambrose now", etc.).
- The printed data is easily reviewed and readily shows up suspect dumps.
- In all three configurations, the system offers a high legal effectivity.
- The system uses proven, off-the-shelf hardware and concepts. High reliability is thus expected. When failures do occur, the unit plug-in concept permits easy dockside maintenance and minimal vessel delay.
- Operation is simple and easily learned by Captain and mate.

- Vessel position is displayed for use by the Captain at his discretion. (This will probably prove to be a valuable navigation aid should the dump sites move further offshore.)
- The need for maintenance is quickly and accurately evident to the Captain or mate.
- The system can tolerate a wide variation of ships power input (nominally 100w at 32v DC, but 11v DC to 65v DC is acceptable).

11.2 PHYSICAL DESCRIPTION

11.2.1 LEPS

When installed there are only two apparent elements to the LEPS, namely the Equipment Rack and the whip Antenna. For convenience in handling during installation and maintenance, there are four plug-in units packaged in the Equipment Rack. The LEPS thus comprises the six units with Unit Designation (UD) 101 through 106 as shown in Table 11-1. The Equipment Rack, housing in one case the complete LEPS (less antenna), is to be mounted in the wheelhouse. Two different size Equipment Racks are offered as shown in Table 11-1 to accommodate different wheelhouse space available on different vessels. The basic block diagram for LEPS is shown in Figure 4-3.

TABLE 11-1

UNITS FOR LEPS & DELPS

UD	Component	Qty/System	Approx. Size
101	Antenna	1	15 ft. Whip
102, 103	Loran Receiver	2	14" x 9" x 12"
104	Printer Unit	1	9" x 6" x 18"
106	Equipment Rack	1	26" x 19" x 20"

OR, Option 1 (for use when less floor space is available):

TABLE 11-1 (Cont.)

UD	Component	Qty/System	Approx. Size
106-A	Equipment Rack	1	16" x 32" x 20"
Plus Option 2 (added when positive dump sensing is needed):			
107	Draft Sensing Unit	1	10" x 17" x 5"

11.2.2 DELPS

When positive dump sensing is desired, the DELPS may be obtained from the basic system, LEPS, by the simple addition of the Draft Sensing Unit, UD 107, as shown in Table 11-1. The Draft Sensing Unit comprises eight pressure switches, preset for each installation to switch in sequence at the following fractional parts of full load: 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16 and Full. These switch outputs provide discretes for appropriate recording on one channel of the digital printer. The unit is connected to sea pressure via a 1/4" pipe line, which can be made up ship board of an existing sea cock or to a simple sea chest. No difficulty from sea waves is anticipated, but if necessary a damping pot could be added. The basic block diagram for DELPS is shown in Figure 4-2.

11.2.3 SIDS

When the positive dump sensing is to be obtained from a towed scow, the tug is equipped with the basic system (LEPS) and the scow is equipped with a scow indicating dump system, SIDS. The SIDS comprises the two units as shown in Table 11-2. The Draft Sensing Unit, UD 201, is the same as the DELPS UD 107. The Recorder Unit, UD 202, is a unit comprising a resistor bank, an analog printer, a "mark now" button and "on-off" switch. The resistor bank is connected to the switches of the Draft Sensing Unit so

that a stepped current proportional to the pre-set step changes in draft is recorded on the analog printer (such as Rustrak Model 288). The SIDS requires less than 50 ma at 12V DC nominal and would normally operate from the scow's batteries. However, if necessary, this low power demand can be provided by a re-chargeable external battery pack good for at least 100 hours between charges. The basic block diagram for SIDS is shown in Figure 4-2.

TABLE 11-2

UNITS FOR SIDS

UD	Component	Qty/System	Approx. Size
201	Draft Sensing Unit	1	10" x 17" x 15"
202	Recorder Unit	1	8" x 14" x 10"

11.3 FUNCTIONAL DESCRIPTION

11.3.1 IEPS

A Functional Flow Diagram for IEPS, showing also the electrical interface signals is presented in Figure 11-1. The two Loran receivers, UD 102 and UD 103 provide two hyperbolic lines-of-position (lop), to establish CEP vessel position to better than 0.25 nmi. The two Loran receivers automatically track the pre-selected Loran A station pairs after the station masters are manually acquired by the Captain (a very simple procedure). The two lop's are displayed on nixie tubes on the receiver front panels. The two lop's are also transmitted to the printer and are automatically printed every six (6) minutes and every fifteen (15) seconds for two minutes immediately following each "event". This is timed by an electronic clock in the events unit. The clock is used to transmit relative time to the printer. The events unit also contains ten (10) buttons which are depressed to indicate, and record in coded form,

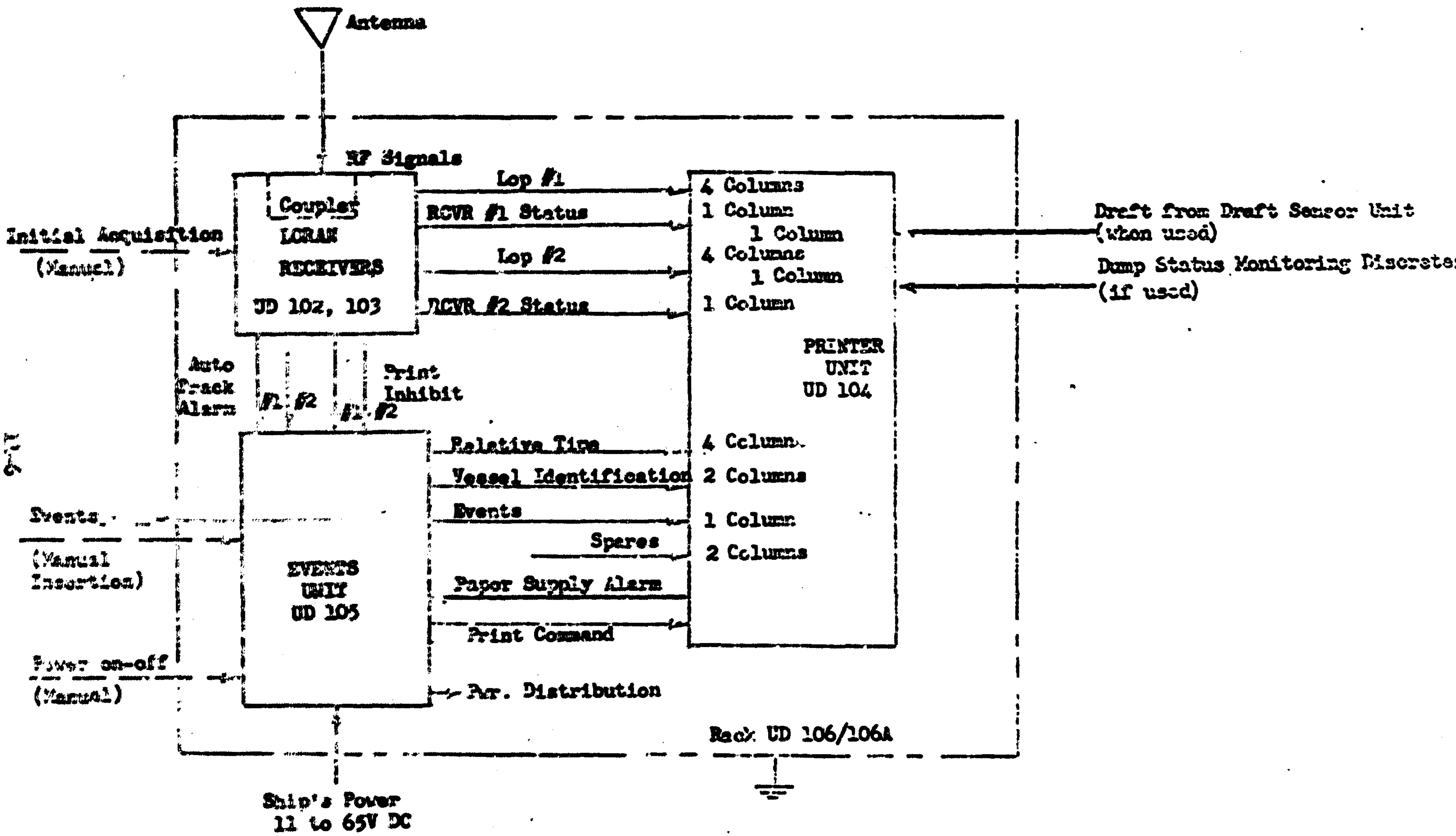


Figure 11-1 LEPS Functional Flow Diagram

the occurrence of a particular "event", such as shown in Table 11-3. Note that five of the buttons are changeable, pre-set to accommodate different vessels, routes, etc., and that one button is used to synchronize recorded data of SIDS with LEPS.

TABLE 11-3

EVENTS UNIT BUTTONS

Button No.	Event
1	Leaving Dock Now
2	Starting Dump Now
3	Completing Dump Now
4	Return to Dock Now
5	Passing Fixpoint No. 1 (e.g. Buoy "xx")
6	Passing Fixpoint No. 2 (e.g. Ambrose)
7-9	Additional Customized Events
10	"Mark Now" (for synchronizing with SIDS)

Signals showing status of the two Loran receivers are also printed. In addition, loss of automatic track in the Loran receivers will actuate a visible and audible alarm in the Events Unit. Appropriate print-inhibit signals are used to prevent printing during any interval when the lop registers are being updated. A visible and audible alarm shall also be provided to indicate an approaching need for replacement of printer paper. The printer is a 21-channel alpha-numeric printer using 3.5" paper tape. The channel allocation is shown in Table 11-4.

TABLE 11-4

PRINTER COLUMN ALLOCATIONS

Column	Function
1 and 2	Vessel identification
3	Events
4 and 5	Spares
6 through 9	Relative Time
10	Draft (when used)
11	Status, Loran Rcvr. No. 2
12 through 15	LOP No. 2
16	Dump Status (if used)
17	Status, Loran Rcvr. No. 1
18 through 21	LOP No. 1

At the end of each dump trip the Captain signs the recorded data certifying its validity and delivers it to NEDCE by Courier or posts it in U.S. mails within 12 hours after return to port, using pre-addressed envelopes provided by NEDCE. The delivered data is quickly reviewed for place of dump and for total trip elapsed time to identify suspect dumps for further examination.

11.3.2 DELPS

As previously described, DELPS is formed by adding positive dump sensing to the basic system, LEPS. This is accomplished by connecting the Draft Sensing Unit to sense external water pressure and thus vessel draft. The Draft Sensor Unit comprises eight pre-set pressure switches, adjusted to throw at pre-set pressures representing the following fractional parts of full load: 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16, Full. Note that the size of the steps are less nearer to full load. The outputs of these switches are

draft discretes connected electrically to be recorded on one channel of the digital printer, as shown in Figure 11-1.

11.3.3 SIDS

As previously described in paragraph 11.2.3, SIDS comprises two units, namely a Draft Sensor Unit (same unit as for DELPS) and a Recorder Unit. In this case, the draft is recorded aboard the scow by SIDS (this approach permits operation without a data link between the tug and the towed scow). The draft recorded data must be time-coordinated with the LEPS recording. This is accomplished by simultaneously depressing "mark now" buttons on SIDS and on LEPS at the start and the end of each trip (conceivably at the time the tug hawser is made fast and is released). An additional checkpoint exists at the time of dump when the tug captain depresses the start and completion of dump buttons and a corresponding change in draft should occur on the SIDS recording. (The strip paper drive for the SIDS recording is at a fixed speed within 2%.)

11.4 COMMENTS ON LEGAL EFFECTIVITY

The printed data of LEPS provides a complete timed history of the entire dump mission. The continuous timed record of vessel position with indications of specific locations at specific times ("events") would be very difficult to fabricate or to manipulate or to tamper with. In addition, the print-out is in English language (with only a simple coding for events) so that the Captain can make an intelligent review, thereby making his signature more meaningful. Accordingly, it may be expected that the data usually will be a true representation of the dump trip.

It may be noted that, when only LEPS is used, the occurrence of dump is indicated only by the Captain depressing the corresponding events button

for start of dump and completion of dump. Accordingly, the integrity of the Captain is relied upon and, of course, this always can be challenged. He might purposely misrepresent or, making a human error, he may "forget" to depress these events buttons at the correct time if at all. The review of such data would then simply look for the farthest traveled point, (generally the turn-around point) as determined by the two lop's. It is then assumed that the dump occurred at that point. Certainly the dump did not occur at a further point, since the vessel travelled no further. The dump may have occurred earlier -- but this is not very likely since there is normally nothing to be gained by dumping early and then travelling further. However, in some situations early dumps are anticipated (such as a trickling dump made for comfort in heavy weather with the hope of escaping detection). In fact, an early dump might be attempted at times by almost any Captain. For these cases positive detection of occurrence of dump should be made, using DELPS or SIDS.

Should experience show that additional independent sensing of the occurrence of dump is necessary, recording the status of dump control valves, actuators, scow doors, etc., can be added. Printer spare column 16 (ref. Table 11-4) has been reserved for this use to give a separate indication of the time of dump. However, it is felt that for many situations the LEPS alone or with SIDS or DELPS will be adequate without such addition.

It is realized that the major purpose of a DMS is not to increase the exchequer by fines won in court cases, but rather it is to control ocean dumping practices. In this regard, the value of the DMS as a deterrent to illegal or improper practices is important. The systems defined are believed to provide as strong a deterrent as would be provided by more sophisticated,

more costly systems. Of course, an empty "black-box" will initially provide a strong deterrent too (that is, until the Captain learns that the box is ineffective in catching violations). The defined preferred systems provide a rather high confidence that violations will be detected and thus should retain their value as deterrents.

It is expected that "suspect" dumps will be resolved more often out of court than in court. It is likely, however, that the Captain involved will be given strong warnings, such as might occur, for example, if a particular Captain delivered data establishing a pattern of abnormally frequent loss of Loran auto track (and thus no [illegible] data for such trips). The NYDCE could add weight to the impact of the warnings by barring the renegade Captain from dump vessels upon the second warning; barring the vessel/owner from dump activities upon the third warning, etc.

Finally, it is suggested that the Corps of Engineers keep sight of the fact that not only is the relatively high-cost monitoring of ocean dumping required to help protect the environment, but that the ocean may be the only logical place to dispose of much of the waste and, accordingly, that any monitoring activity should not stifle ocean dumping but rather should facilitate the proper disposal of waste in the ocean.

SECTION 12.0

IMPLEMENTATION PLAN

An implementation plan is presented leading to an operational DMS nine (9) months after contract award. The selected DMS uses the Loran-Events-Printer System (LEPS) as the basic system to which is added a Draft Sensing Unit to make a DELPS and a Scow Indicating Draft System, SIDS, aboard a towed scow to provide positive dump sensing. This section discusses hardware procurement, installation and checkout, operation and maintenance, and provides planning cost estimates and time schedules.

12.1 GENERAL

Key factors vital to the development of the LEPS Instrumentation Plan are determinations of the number of systems needed and vessel assignment or other usage of the systems. Examination of the ocean dumping operations in the greater New York Harbor has led to the following recommendations regarding the number and usage of systems. It should be remembered that ownership (and therefore responsibility for maintenance) of the equipment is to be retained by the Corps of Engineers.

It is recommended that there be two separate procurements of systems to cover present operations. The "initial buy" would procure twenty-four (24) systems. The "second buy" would procure an additional forty-two (42) systems. The two separate buys are suggested for flexibility of funding which might be in two different fiscal years. Table 12-1 shows the suggested usage of these systems and the recommended numbers and usages of DELPS and SIDS. Note that the initial buy of 24 systems provides for use of 13 DELPS, 3 LEPS with SIDS, and 4 LEPS for portable use. The initial buy allowance for spares

TABLE 12-1

[redacted] RECOMMENDED PROCUREMENTS AND USAGES

Usage	Initial Buy DELPS	Initial Buy SIDS	Initial Buy LEPS	Initial Buy TOTAL	Second Buy DELPS	Second Buy SIDS	Second Buy LEPS	Second Buy TOTAL
Assigned to vessel owners								
Sewer Sludge	11	0	0	11	2	0	0	2
Industrial/Chemical Wastes	2	3	3	5	0	2	2	2
Dredge Spoils	-	-	-	-	0	8	8	8
Cellar Dirt, etc.	-	-	-	-	0	15	15	15
Presently unidentified	-	-	-	-	2	2	2	4
Portable Systems	0	0	4	4	0	0	3	3
(Sub Total)	13	3	7	20	4	27	30	34
Spare Systems								
Dockside Maintenance	2	1	0	2	1	3	3	4
Pipeline Allowance	2	1	0	2	1	3	3	4
(TOTAL)	17	5	7	24	6	33	36	42

is 4 DELPS (which also spares the LEPS) and 2 SIDS (making about 4 systems worth of spares). Similarly, note that the second buy provides for use of 4 DELPS, 27 LEPS with SIDS and 3 LEPS for portable use. plus corresponding spares.

Probably the dumping of sewer sludge and toxic industrial/chemical waste represent the most severe form of ocean dumping occuring regularly in the New York Bight and, accordingly, should be covered in the initial buy as shown in Table 12-1. The eleven (11) systems allocated to monitoring of sewer sludge dumping would cover New York City (5), Nassau (1), Westchester (1), and New Jersey (4). The five (5) systems for industrial/chemical waste would cover the present requirements such as for National Lead, Allied Chemical, Speltonbush/Sparkling Waters, Modern Transportation. The systems shown for these usages in the second buy are recommended to cover additional anticipated requirements such as caused by additional plants producing sewer sludge and caused by the need to carry to sea those industrial wastes presently being discharged into streams where such continued practice cannot be licensed.

As shown, it is suggested that four (4) systems of the initial buy and three (3) systems of the second buy be kept as "portable systems" for use, as deemed appropriate, aboard any vessel. It is quickly noted that the numbers of portable systems decreases between initial and second buys from 25% to 10% of the numbers of systems of each buy assigned to vessel owners. The larger percentage initial buy is recommended to cover the larger percentage of dumping operations not under surveillance by installed systems of the initial procurement. These systems should be LEPS.

The second buy includes eight (8) systems for assignment to monitor dumping of dredge spoils. These eight systems would cover operations involving about 37 barges and, for example, might be assigned to Great Lakes (5), American Dredging (2), and Dunbar & Sullivan (1). The fifteen (15) systems recommended for the second buy to monitor dumping of cellar dirt, etc., would cover operations involving about 47 tugs and, for example, might be assigned to Moran Towing (6), McAllister (5), Turecamo (3), and Red Star (1). The basic LEPS part of these systems might be used as portable equipment aboard a number of previously prepared tugs. (The towing company might separately procure antennas and racks to facilitate the flexibility.) The SIDS would be installed in the assigned dump scows. Since delivery of the systems of the second buy might be as much as two years away, it is quite likely that additional assignments and different priorities will be identified. It is felt that a reasonable allowance for this would be four (4) systems to be assigned but, as shown, presently unidentified.

Spare systems are recommended, as shown, for both the initial and second buys, amounting to about 10% for dockside maintenance and a pipeline allowance of about 10%. These spares will provide the needed plug-in units to support the recommended dockside maintenance philosophy to minimize vessel delay caused by an equipment failure or malfunction. Of course, the pipeline allowance provides the needed units to stay operational while faulty units are in the repair "pipeline" (at or enroute to or from repair shops or factories). The selection of the number of spares recommended is based on our experience and is expected to yield a high confidence (say greater than 95% confidence level) that a spare unit will be available when needed for a reasonable period (say at least two years). A rigorous sparing analysis,

which is not within the scope of this planning study, could be made using any of several programs developed for digital computers (such as by SSMD) to determine the number of spares required to support a given program for various confidence limits and operating times. The mathematics for such programs, typically based on an exponential or Poisson distribution of failure times for component parts, requires a knowledge of failure rates and, of course, the detail parts are not yet fully identified for the systems. Accordingly, it is suggested that the recommended quantity of spares be procured and that maintenance records be kept so that the failure history could be watched closely and additional quantities of any critical units thus identified could be procured. Such records would also form the basis for future spares buys (it is most likely that unequal quantities of the various units would be desired).

It should further be noted that the quantities recommended for the initial and the second buys, are based upon an analysis of present dumping operations in dump sites near Ambrose Light Tower with only an occasional dump as far as 106 n mi offshore. Should the licensed dump areas move significantly offshore, the round-trip time would increase substantially, and more vessels could be required to dump the same amount of waste. Accordingly, in such a case, the quantities and assignments of systems should be re-examined.

12.2 HARDWARE PROCUREMENT

The systems comprise automatic Loran Receivers, a digital printer, and an analog printer which are basically off-the-shelf with only minor modification. However, the Events Unit, and the Draft Sensing Unit involve

a unique arrangement of proven concepts and existing hardware and thus require design effort. Similarly, the system interfaces and the equipment racks are unique and also require design activity. The plan calls for the design effort to be a part of the hardware procurement of the initial buy resulting in equipment deliveries from the eighth through the eleventh month after authorization, as shown in Figure 12-1. The initial buy would also cover the preparation and delivery, four months after authorization, of a Notice of Plan, Installation Instructions, and Operating Instructions for users and for the Corps of Engineers. The Notice of Plan would be used by NYDCE to advise users and potential users of the plan to monitor ocean dumping and of the timetable and regulations for the start of use of the systems and the requirement to submit the recorded data. The Installation Instructions would cover details concerning installation so that, regardless of vessel configuration, a vessel could be prepared for installation of a permanent system or portable system. The User Operating Instructions would show, in check-list form and in back-up detail, the step-by-step procedures for use of the equipment and delivery of data to NYDCE. Additional instructions for use by NYDCE would cover their operations also in check-list form and with back-up detail.

12.3 INSTALLATION AND CHECKOUT

The various vessels would be prepared by the owners to receive the systems. The preparation for LEPS involves assigning locations and providing mounting holes/foundations for the antenna and equipment rack, running a coaxial r-f cable between the antenna and rack, and providing to the rack an r-f

ground and low-level primary electric power (nominally 100w at 32VDC). The additional vessel preparations for DELPS involves assigning a location and providing mounting holes/foundation for the Draft Sensing Unit, and running a 12-wire signal cable from that location to the location of the LEPS rack. For a SIDS, the vessel preparation involves assigning locations and providing mounting holes/foundations for the Draft Sensing Unit and the Recorder Unit, running a 12-wire signal cable between the two, and providing to the Recorder Unit low-level primary power (nominally 1.0 watts at 12v DC). Inspection of the prepared vessel will be subject to review and approval by NYDCE prior to installation of equipment. The equipment will be installed and checked out by NYDCE in the presence of the owner. Preferablly at the time of equipment installation and checkout, the captain (and owner and mate, if desired) will be given training in the relatively simple operating procedures.

It is recommended that NYDCE contract with SSID to provide these inspection, installation, checkout and training functions as well as the maintenance function described in Paragraph 12.4, below.

12.4 OPERATION AND MAINTENANCE

A typical operation starts at a dock or loading area. The captain turns the equipment "ON" and enters the following information in written english on a rubber-stamp like form on the paper tape at the start for this trip:

- Identification of vessel
- Name of owner
- Identification of load
- Place of departure
- Location of dump
- Name of captain
- Identification of covering permit.

The captain then acquires the two pre-selected master Loran signals. The two Loran Receivers automatically acquire the slave signals and automatically track, thus providing and continuously up-dating the two Loran lines-of position. Thereupon the Printer automatically records the two lines-of-position and time each six (6) minutes as determined by a clock in the Events Unit. (Loss of Loran track is indicated by a visible and audible alarm, and the two lop's are displayed on the face of the Loran units for use as a navigation aid at the discretion of the captain.)

When used with SIDS, at the time the tug's hawser is made fast to the scow, the LEPS and SIDS recordings are synchronized by simultaneously depressing a "mark now" button on the SIDS Recorder Unit and a "mark now" button on the LEPS Events Unit in response to some prearranged signal. (Similarly, the two recordings are again marked when the trip is completed and the hawser is being detached.) When SIDS is not used, a pre-assigned button on the Events Unit is depressed by the captain at a pre-defined point (e.g., passing buoy #XX) to signify departure. Other pre-selected events are pre-assigned to other buttons on the Events Unit (e.g., Passing Ambrose, start of dump, dump completed, etc.). Whenever an events button is depressed, the normal six-minute recording period is interrupted, the specific event is recorded by the Printer along with time and, regardless of clock time, a complete set of data is recorded at 15 second intervals for two minutes.

Upon return to port, the captain enters the date, time, and place and signs the printed tape (and that from SIDS where applicable), signifying he certifies that the data was recorded on the specific trip and was not manipulated in any way. He then delivers the data within 12 hours after return to port, for example, using pre-addressed envelopes provided

by NYDCE.

Of course, the captain is also required to keep his normal ship's log and to report by radio to the harbor supervisor each dump trip departure and return. Similarly, he is required to report to the harbor supervisor any LEPS equipment failure or suspected malfunction based upon failure alarms on the equipment or suspicious performance such as continuous loss of Loran track, or incorrect Loran readings at navigation points where the correct readings are well-known, etc.

All data delivered to the NYDCE is briefly reviewed to reveal suspects, and the data is examined in detail for any dump suspected of being improper (see also comments re this in Paragraph 3.3). Although not a part of the recommended plan, it is suggested that NYDCE consider a contract to a third party, such as SSMD, to receive and file, and review and examine, all recorded data and to identify violations for further action.

Reports of equipment failure or malfunction would result in the timely dispatch of a trained maintenance man and spares to the vessel at dockside so that there would be a minimal delay, indeed if any, in the vessel's next trip. The dockside maintenance, to be accomplished only by NYDCE, is based upon replacement of the faulty plug-in unit by a good spare unit. The removed unit would be carried back to the shop for further diagnosis and repair or returned to the factory for repair. It is recommended that NYDCE give a "Maintenance Contract" to SSMD to cover this maintenance and the inspection, installation, checkout and training functions described in Paragraph 12.3, above.

12.5 PLANNING COST ESTIMATES AND TIME SCHEDULES

Estimated costs for equipment procurement in accord with this implementation plan are shown in Table 12-2. A breakdown is shown to give some visibility regarding the origin of the estimates. It should be remembered that the initial buy includes the start-up costs (e.g., design of the Events Unit and Equipment Racks, and generation of notices and instructions). However, even without these start-up costs, the systems of the second buy are significantly lower than for the initial buy (e.g., approximately $9K vs. $11K for LEPS) and so reflect an expected learning curve. The value of the "Maintenance Contract", which is not included in Table 12-2 is about $60K per year and is based on approximately 24 man-months of field engineering. The maintenance contract should start about the sixth month after procurement authorization. An allowance of about $500/DMS/yr. should be made in budget planning to cover the costs of detail repairs in shops or factory. The schedule milestones are shown in Figure 12-1. An additional allowance for approximately 18 m-months/year of engineering should be made for a contract to file and review recorded data.

It should be noted that the estimates are at the "cost-line" and do not include fee. It might also be appropriate for budget planning to include an allowance (say 10%) as a reserve to cover items possibly overlooked.

TABLE 12-2

PROCUREMENT COSTS

A. BASIC SYSTEM (LEPS)

Description	Initial Buy	Second Buy
Scientist & Superv. Engineer	$ 37,300	$ 32,900
Senior Engineer	97,200	43,600
Engineer	8,300	-
Drafting/Layout	32,000	-
Factory Labor	10,500	15,700
External Subcontract Mat'l.	154,000	257,000
Product Material	24,800	39,900
Pubs Material	1,500	1,100
Travel	1,300	600
Total Cost	$366,900	$390,800
Number of Systems	24	42
Total Average Cost/System	$ 15,300	$ 9,400
Total Average Cost for 66 Systems	$11,400/LEPS	

B. INCREMENT FOR DELPS

	Initial Buy	Second Buy
Starting Costs	$ 13,500	$ -0-
Running Costs	5,600	1,900
Total Cost	$ 19,100	$ 1,900
Number of DELPS	17	6
Average Incremental Cost	$ 920/DELPS	

C. INCREMENT FOR SIDS

	Initial Buy	Second Buy
Starting Costs	$ 10,400	$ -0-
Running Costs	3,600	22,800
Total Cost	$ 14,000	$ 22,800
Number of SIDS	5	33
Average Incremental Cost	$ 970/SIDS	

Figure 12-1 - Schedule Milestones

DESCRIPTION	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
																								MONTHS AFTER AUTHORIZATION
[illegible] Deliveries							5	8	8	3														
(Issued To [illegible])							(3)	(2)	(2)	(1)														
([illegible])							(1)	(1)	(1)	(1)														
(For Spares)							(1)	(1)	(1)	(1)														
[illegible] of Plan [illegible]																								
Installation Instructions																								
[illegible] Instructions																								
[illegible] Operating Instructions																								
Install [illegible] & Checkout																								
Maintenance [illegible]																								
System "[illegible]"																								
[illegible] Buy																								
"Go-Ahead"																								
Equipment Deliveries													2	7	7	10	10	4						
(For Spares)													(6)	(2)	(2)	(2)	(1)	(1)						
Install Equipment & Checkout																								

12-12

15

APPENDIX A

DEFINITION AND MATHEMATICAL FORMULATION OF LOCATION POSITIONAL ACCURACY

Vessel location position accuracy as used in this report is defined as the probability of locating the vessel to within a specified circular dump radius. To determine a location fix, a minimum of two measurements are required from a single or multiple reference datum. With a single reference datum point the measurements will consist of a bearing and a range. With two reference datum points, either two ranges, two bearings or a combination of the two are required. With a hyperbolic navigational system, the intersection of two hyperbolics at the vessel position establishes the location fix. In all of these system approaches, the two measurements are made with error caused by systematic or predictable errors and/or unsystematic or random errors. The unsystematic errors are subject to a distribution according to a Gaussian error function which are describable by the standard deviation and the mean or bias. When two or more errors are combined, it is generally assumed the errors are independent unless known to the contrary. Combining errors for a two dimensional error system (bivariate normal distribution) is performed using statistical techniques which apply probability distributions in two dimensions. In this case, a probability ellipse is used to describe the behavior of errors. For the special case of an orthoginal system where the standard deviations for each axis are equal and uncorrelated, the probability ellipse reduces to the special case of a probability circle. It is common practice when dealing with the probability ellipse to utilize an equivalent circular radius to define positional accuracy such that the enclosed positional data has the same probability as the ellipse. The subsections following present the mathematical techniques of determining location positional accuracy for the various location subsystem approaches considered for the Sea Dump Monitoring System.

A-1 TWO BEARING LINES OF POSITION (INTERSECTING BEARINGS)

The calculation of the radial error (radius of uncertainty) for the case of two intersecting bearing lines, each having a bearing error with a standard deviation σ, is based on the probability distribution given in para 3.1 of reference 3... Results for the 95% probability circle have been computed and the tabular results are reproduced in Table A-1. Given the angles of the bearing lines, base length between datum reference (c), and the bearing standard deviationerrors (σ), the radius for a 95% probability is obtained fromthe equation.

Eq. (A-1) $R_{n.mi.} = C_{n.mi.} \times \sigma \times \text{TABLE VALUE}$

For other percent probability circles, assuming orthogonal bivariate normal distributions with equal σ's, the radii of the uncertainty circles are related to the errors by the equation:

Eq. (A-2) $P = 1 - e^{-c^2/2}$ where $c\sigma$ = radius

Table A-2 presents a summary of the results obtained from equation (A-2).

TABLE A-2 PROBABILITY FOR RADII OF UNCERTAINTY

P%	Radius = $c\sigma$	In Terms of CPE
25	.7585 σ	.6442 CPE
39.3	1 σ	.8493 CPE
50	1.177 σ	1.0000 CPE
75	1.665 σ	1.414 CPE
90	2.146 σ	1.823 CPE
95	2.448 σ	2.079 CPE
99	3.035 σ	2.578 CPE

For the general case of a non-orthogonal, bivariate distribution having unequal and correlated errors, a coordinate rotational transformation may be performed which will result in uncorrelated errors in an orthogonal system. It can be shown that the uncorrelated errors are given by:

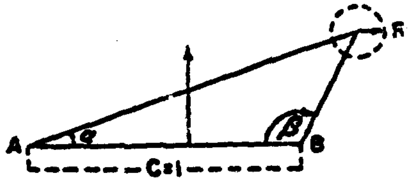
Eq. (A-3)

$$\sigma_x^2 = \sigma_v^2 \cos^2(\theta - \gamma) + 2\sigma_u\sigma_v K_{uv} \cos(\theta-\gamma)\cos\gamma + \sigma_u^2 \cos^2\gamma$$

$$\sigma_y^2 = \sigma_v^2 \sin^2(\theta - \gamma) - 2\sigma_u\sigma_v K_{uv} \sin(\theta-\gamma)\sin\gamma + \sigma_u^2 \sin^2\gamma$$

where $$\tan 2\gamma = \frac{\sigma_v^2 \sin 2\theta + 2\sigma_u\sigma_v K_{uv} \sin\theta}{\sigma_v^2 \cos 2\theta + 2\sigma_u\sigma_v K_{uv} \cos\theta + \sigma_u^2}$$

TABLE A-1 95% PROBABILITY RADIAL ERROR FOR RADIO DIRECTION FINDING SYSTEM



W 95%

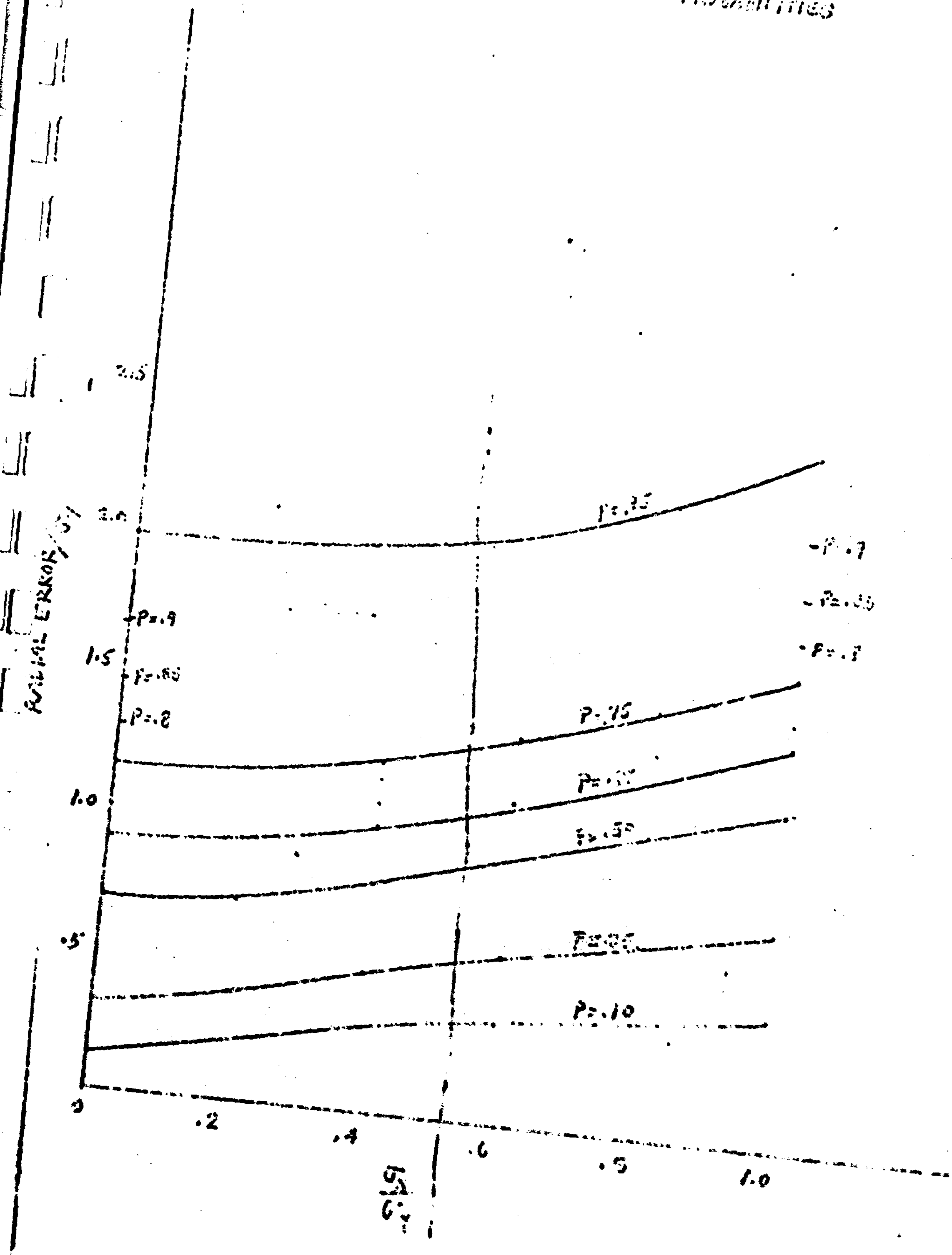
α in Degrees	β = 5°	β = 10°	β = 15°	β = 20°	β = 25°	β = 30°	β = 35°	β = 40°	β = 45°	β = 50°
005	0.1394	0.0968	0.0795	0.0675	0.0583	0.0526	0.0479	0.0442	0.0414	0.0392
010	0.0963	0.0710	0.0588	0.0517	0.0468	0.0432	0.0404	0.0383	0.0366	0.0354
015	0.0795	0.0538	0.0489	0.0433	0.0397	0.0372	0.0355	0.0342	0.0333	0.0327
020	0.0673	0.0517	0.0433	0.0383	0.0353	0.0334	0.0322	0.0314	0.0310	0.0303
025	0.0589	0.0468	0.0397	0.0353	0.0326	0.0309	0.0300	0.0295	0.0294	0.0297
030	0.0526	0.0432	0.0372	0.0334	0.0309	0.0295	0.0287	0.0285	0.0287	0.0292
035	0.0479	0.0404	0.0355	0.0322	0.0300	0.0287	0.0282	0.0282	0.0286	0.0295
040	0.0442	0.0383	0.0342	0.0314	0.0295	0.0285	0.0282	0.0284	0.0292	0.0303
045	0.0414	0.0366	0.0333	0.0310	0.0294	0.0287	0.0285	0.0292	0.0302	0.0318
050	0.0392	0.0354	0.0327	0.0308	0.0297	0.0292	0.0295	0.0303	0.0318	0.0339
055	0.0374	0.0344	0.0323	0.0309	0.0302	0.0301	0.0307	0.0320	0.0339	0.0367
060	0.0361	0.0338	0.0322	0.0313	0.0309	0.0313	0.0323	0.0341	0.0367	0.0402
065	0.0352	0.0334	0.0324	0.0319	0.0320	0.0328	0.0344	0.0368	0.0402	0.0449
070	0.0345	0.0333	0.0328	0.0328	0.0334	0.0347	0.0370	0.0402	0.0447	0.0508
075	0.0341	0.0335	0.0334	0.0339	0.0351	0.0371	0.0402	0.0445	0.0504	0.0584
080	0.0340	0.0338	0.0343	0.0354	0.0373	0.0401	0.0442	0.0499	0.0577	0.0634
085	0.0341	0.0345	0.0355	0.0373	0.0399	0.0438	0.0492	0.0568	0.0672	0.0818
090	0.0345	0.0354	0.0371	0.0396	0.0432	0.0484	0.0556	0.0657	0.0799	0.1002
095	0.0352	0.0367	0.0391	0.0425	0.0474	0.0543	0.0640	0.0777	0.0974	0.1267
100	0.0361	0.0384	0.0416	0.0462	0.0527	0.0619	0.0750	0.0940	0.1224	0.1669
105	0.0375	0.0405	0.0448	0.0509	0.0595	0.0719	0.0901	0.1174	0.1603	0.2324
110	0.0392	0.0432	0.0489	0.0569	0.0686	0.0857	0.1116	0.1526	0.2218	0.3509
115	0.0414	0.0466	0.0541	0.0649	0.0809	0.1052	0.1439	0.2097	0.3327	0.6022
120	0.0442	0.0511	0.0610	0.0757	0.0983	0.1344	0.1962	0.3123	0.5574	
125	0.0479	0.0568	0.0702	0.0909	0.1242	0.1814	0.2896	0.5285		
130	0.0526	0.0646	0.0831	0.1133	0.1656	0.2551	0.4858			
135	0.0588	0.0752	0.1020	0.1489	0.2299	0.4397				
140	0.0673	0.0906	0.1317	0.2113	0.3907					
145	0.0792	0.1142	0.1829	0.3393						
150	0.0970	0.1541	0.2362							
155	0.1259	0.2325								
160	0.1739									

TABLE A-1 (continued)

α in Degrees	β = 55°	β = 60°	β = 65°	β = 70°	β = 75°	β = 80°	β = 85°	β = 90°	β = 95°	β = 100°
005	0.0374	0.0361	0.0352	0.0345	0.0341	0.0340	0.0341	0.0345	0.0352	0.0361
010	0.0344	0.0338	0.0334	0.0333	0.0335	0.0338	0.0345	0.0354	0.0367	0.0384
015	0.0323	0.0322	0.0324	0.0328	0.0334	0.0343	0.0355	0.0371	0.0391	0.0416
020	0.0209	0.0313	0.0319	0.0328	0.0339	0.0354	0.0373	0.0396	0.0425	0.0462
025	0.0302	0.0309	0.0320	0.0334	0.0351	0.0373	0.0399	0.0432	0.0474	0.0527
030	0.0301	0.0313	0.0328	0.0347	0.0371	0.0401	0.0438	0.0484	0.0543	0.0619
035	0.0307	0.0323	0.0344	0.0370	0.0402	0.0442	0.0492	0.0556	0.0640	0.0750
040	0.0320	0.0341	0.0368	0.0402	0.0445	0.0499	0.0568	0.0657	0.0777	0.0910
045	0.0339	0.0367	0.0402	0.0447	0.0504	0.0577	0.0672	0.0799	0.0974	0.1224
050	0.0367	0.0402	0.0449	0.0508	0.0584	0.0684	0.0313	0.1002	0.1267	0.1669
055	0.0403	0.0449	0.0510	0.0589	0.0692	0.0832	0.1024	0.1302	0.1724	0.2414
060	0.0449	0.0511	0.0591	0.0697	0.0841	0.1041	0.1329	0.1763	0.2437	0.3794
065	0.0510	0.0591	0.0699	0.0846	0.1050	0.1347	0.1799	0.2542	0.3896	0.6791
070	0.0589	0.0697	0.0346	0.1054	0.1355	0.1818	0.2579	0.3970	0.6949	
075	0.0692	0.0811	0.1050	0.1356	0.1824	0.2593	0.4014	0.7055		
080	0.0832	0.1041	0.1347	0.1818	0.2598	0.4029	0.7103			
085	0.1024	0.1329	0.1799	0.2579	0.4014	0.7103				
090	0.1302	0.1763	0.2542	0.3970	0.7055					
095	0.1724	0.2437	0.3896	0.6949						
100	0.2414	0.3794	0.6791							
105	0.3665	0.6583								
110	0.6326									

α in Degrees	β = 105°	β = 110°	β = 115°	β = 120°	β = 125°	β = 130°	β = 135°	β = 140°	β = 145°	β = 150°	β = 155°
005	0.0375	0.0392	0.0414	0.0442	0.0479	0.0526	0.0598	0.0673	0.0792	0.0970	0.1259
010	0.0405	0.0432	0.0466	0.0511	0.0568	0.0646	0.0752	0.0906	0.1142	0.1341	0.2325
015	0.0448	0.0489	0.0541	0.0610	0.0702	0.0831	0.1020	0.1317	0.1829	0.2862	
020	0.0509	0.0569	0.0649	0.0757	0.0909	0.1133	0.1489	0.2113	0.3393		
025	0.0595	0.0686	0.0809	0.0983	0.1242	0.1656	0.2389	0.3507			
030	0.0719	0.0857	0.1052	0.1344	0.1814	0.2631	0.4397				
035	0.0901	0.1116	0.1439	0.1962	0.2896	0.4858					
040	0.1174	0.1526	0.2097	0.3123	0.5283						
045	0.1603	0.2218	0.3327	0.5674							
050	0.2324	0.3509	0.6022								
055	0.3665	0.6326									
060	0.6583										

FIGURE A-1 EQUIVALENT RADIAL ERROR FOR ORTHOGONAL BIVARIATE SYSTEM WITH UNEQUAL σ's FOR VARIOUS PROBABILITIES



Thus, given σ_1, σ_2, angle of intersection θ and correlation factor K_{xy} the errors σ_x, σ_y in an arthogonal set are obtained which are uncorrelated. The unequal σ's yields a probability ellipse contour rather than probability circles obtained for the case of an orthogonal bivariate system with equal and uncorrelated σ's. An equivalent circular area resulting in the same probability, however, may be obtained using the curves in Figure A-1. If $\sigma_x = \sigma_y$ (i.e. $\frac{\sigma_x}{\sigma_y} = 1$), the radial error/$\sigma_y$ ratio corresponds to the tabular results of Table A-2. If $\frac{\sigma_x}{\sigma_y} = 0$, the results shown correspond to the one dimensional distribution case. It is to be noted that the 50% probability curve is usually referred to as the circular error probability (CEP) curve. (See reference 5, Figure A-1).

A-2 HYPERBOLIC NAVIGATION SYSTEMS

In hyperbolic navigation systems, the positional accuracy determined from intersecting hyperbolas is a function of the crossing angle and the accuracy of the lines of positions. The exact equation of the radial error obtained via digital computer is given in reference 3, p. 161 as:

Eq. (A-6)
$$P\left(\frac{R}{d_{rms}}, \gamma\right) = \frac{2}{\pi} \int_0^{\pi/2} \frac{1 - e^{\left[-\frac{1}{2}\left(\frac{R}{d_{rms}}\right)^2 \left(1+\frac{1}{\gamma}\right)\left(\frac{1}{\gamma}\cos^2\phi + \gamma \sin^2\phi\right)\right]}}{\frac{1}{\gamma}\cos^2\phi + \gamma\sin^2\phi}\, d\phi$$

where

ϕ = plane angle over integration period

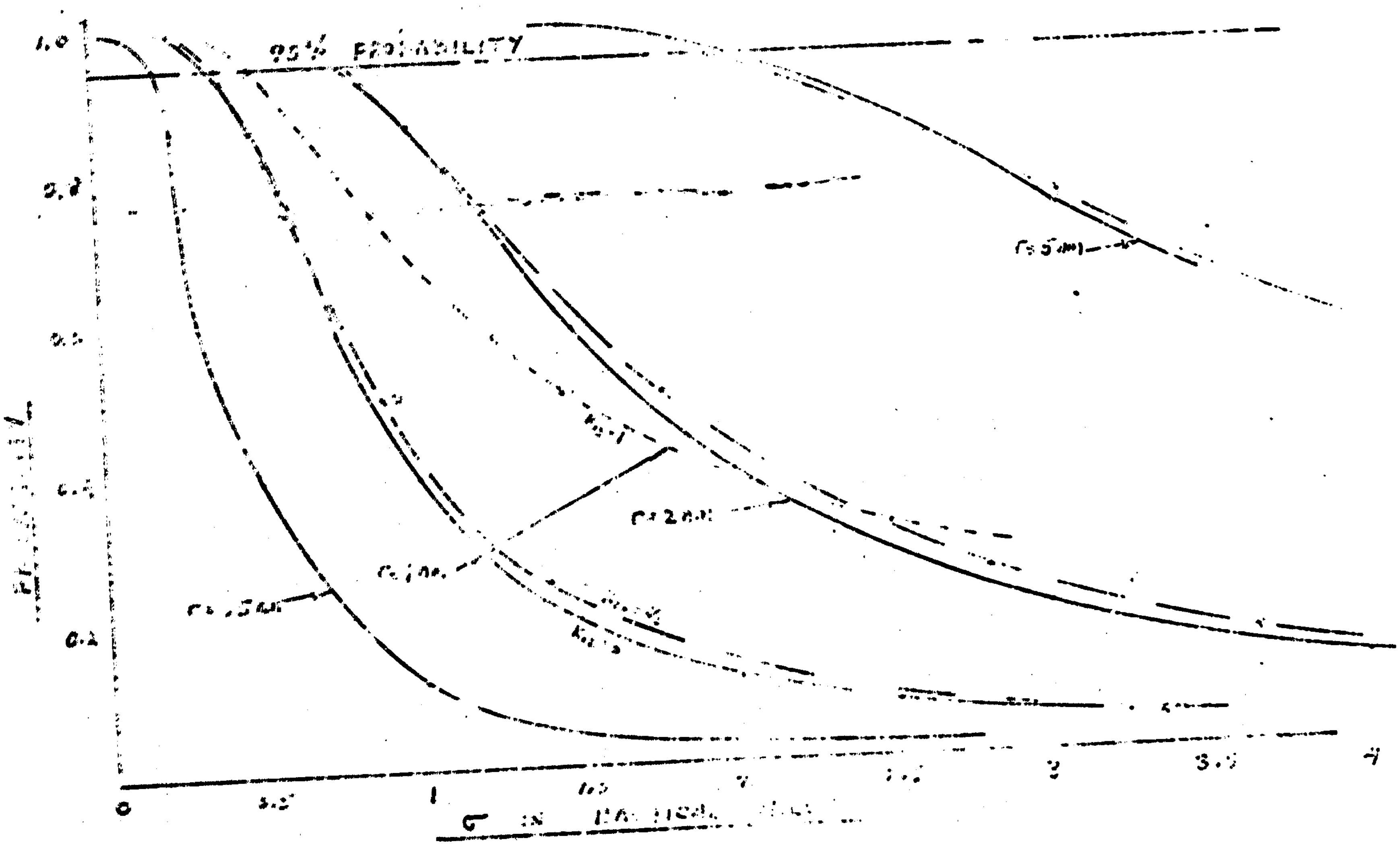
γ = ratio of σ_s^2 of intersecting hyperbolas, reduced to rectangular coordinates

d_{rms} = rms error (63% Probability) given by

(A-7)
$$d_{rms} = \sqrt{\frac{\sigma_1^2 + \sigma_2^2 - 2K_{12}\,\sigma_1\sigma_2\cos\beta}{\sin^2\beta}}$$
where β = crossing angle of LOP

FIGURE A-? PROBABILITY OF ... LOCATION WITHIN ASSIGNED ... AREA OF RADIUS "r" FOR ... DISTRIBUTION HAVING $\sigma_x = \sigma_y = \sigma$

For $K_{ij}=0$, $P = 1 - e^{-\frac{r^2}{2\sigma^2}}$
K_{ij} = CORRELATION COEFFICIENT



Solution of equation A6 is difficult requiring use of a digital computer. It has been general practice to utilize 2 drms as the 95% probability value for the equivalent circular radius. The procedure outlined previously for case 1 for non-orthogonal, unequal and correlated σ's can be utilized to determine the equivalent circular radius for other probabilities. Figure A-1 presents probability as a function of σ's for equivalent circular radius for orthogonal, uncorrelated and equal σ's, orthogonal and correlated equal σ's and non-orthogonal, uncorrelated equal σ's. It is shown that, for correlation factors less than 1/2 and non-orthogonal systems having vertical angles up to 45°, the results for the orthogonal, bivariate distribution having equal σ's can provide an approximate solution for hyperbolic systems. If crossing angles are severe and correlation factors are greater than 1/2, it is advisable to utilize the transformation procedure outlined in section A-1.

A-3 RANGE-BEARING (ρ-θ) SYSTEMS

The probability function for rho-theta systems is given by the equation

$$(A\text{-}9) \qquad P\left(\frac{R}{2\rho\sigma_\theta}\right) = \frac{2\rho\sigma_\theta}{\sigma_\rho}\int_0^{\left(R/2\rho\sigma_\theta\right)^2} e^{-z\left(\frac{\rho^2\sigma_\theta^2}{\sigma_\rho^2}+1\right)} \times I_0\left[z\left(\frac{\rho^2\sigma_\theta^2}{\sigma_\rho^2}-1\right)\right] dz$$

where

$z = r^2/4\rho^2\sigma_\theta^2$

σ_θ = standard derivation of bearing error

σ_ρ = standard deviation of radial error

ρ = distance to target

I_0 = Bessel function of the first kind, zero order

If it is assumed that the distance error is proportional to distance ($\sigma_\rho = S\cdot\rho$) where S = % inaccuracy of distance, equation (A8) is simplified and solution results are given in Table A3. For given standard deviations in range and bearing, and fix distance, the circular radius is computed from the equation

(A9) $R = \rho \times$ Table Value

Radii, for other probabilities not included in the tabular values can be determined as outlined in Section A-1.

Table A3. The Radial Error R (Radius of the Circle of Uncertainty) of Rho-Theta Navigation Systems

	Probability Degrees	90 per cent	95 per cent	98 per cent	— over n.m.
s = 2.0 per cent σ_θ =	0.5	0.0342	0.0403	0.0475	20
	1.0	0.0403	0.0460	0.0527	20
	1.5	0.0501	0.0575	0.0622	20
	2.0	0.0620	0.0722	0.0813	20
	2.5	0.0750	0.0882	0.1037	20
	3.0	0.0887	0.1047	0.1236	10
	3.5	0.1026	0.1215	0.1436	10
	4.0	0.1167	0.1385	0.1637	10
	5.0	0.1450	0.1722	0.2040	10
	6.0	0.1734	0.2062	0.2444	10
s = 1.0 per cent σ_θ =	0.5	0.0201	0.0230	0.0264	20
	1.0	0.0310	0.0361	0.0421	20
	1.5	0.0443	0.0524	0.0618	20
	2.0	0.0583	0.0692	0.0818	20
	2.5	0.0725	0.0851	0.0020	20
	3.0	0.0867	0.1031	0.1222	10
	3.5	0.1010	0.1201	0.1424	10
	4.0	0.1153	0.1372	0.1627	10
	5.0	0.1439	0.1713	0.2032	10
	6.0	0.1725	0.2055	0.2438	10
s = 0.5 per cent σ_θ =	0.5	0.0155	0.0180	0.0211	40
	1.0	0.0292	0.0346	0.0409	40
	1.5	0.0431	0.0515	0.0611	20
	2.0	0.0576	0.0605	0.0813	20
	2.5	0.0720	0.0857	0.1016	20
	3.0	0.0863	0.1027	0.1219	10
	3.5	0.1006	0.1193	0.1422	10
	4.0	0.1149	0.1369	0.1625	10
	5.0	0.1426	0.1711	0.2030	10
	6.0	0.1723	0.2053	0.2136	10
s = 0.2 per cent σ_θ =	0.5	0.0145	0.0172	0.0204	40
	1.0	0.0280	0.0342	0.0406	40
	1.5	0.0431	0.0513	0.0609	20
	2.0	0.0574	0.0681	0.0812	20
	2.5	0.0713	0.0845	0.1015	20
	3.0	0.0851	0.1026	0.1218	10
	3.5	0.1005	0.1197	0.1421	10
	4.0	0.1149	0.1368	0.1624	10
	5.0	0.1430	0.1710	0.2030	10
	6.0	0.1723	0.2052	0.2136	10

APPENDIX B

PERFORMANCE DEGRADATION DUE TO WEATHER ENVIRONMENT

The subsections of this appendix describe the effects of various weather environments on the performance and operational reliability of the key system elements of the DMS candidates.

B-1 RADAR

In inclement weather, the ability of a radar to detect targets is decreased because of attenuation of the radar signal in the path between the radar and target and because of clutter noise from water particles in the vicinity of the target. Attenuation is caused by absorption of water vapor as well as absorption and scattering from water droplets. Clutter noise results from energy scattered in the direction of the receiving antenna and tends to obscure desired signals. In reference 12 of Appendix G, a theoretically derived equation expressing the range capability of a radar in inclement weather as a function of the range capability in dry weather is given in terms of typical radar parameters, attenuation factors for water vapor and scattering, and relative humidity. Figure B-1 presents range degradation of an X band radar in rainfall, assuming the following radar parameters:

Peak Power = 50 KW

Antenna Gain = 28.6 db

Wave Length = 3.2 cm

Noise Figure = 16 db

Pulse Length = 0.6 usec

FIGURE 3-1 RADAR RANGE [illegible] RAINFALL

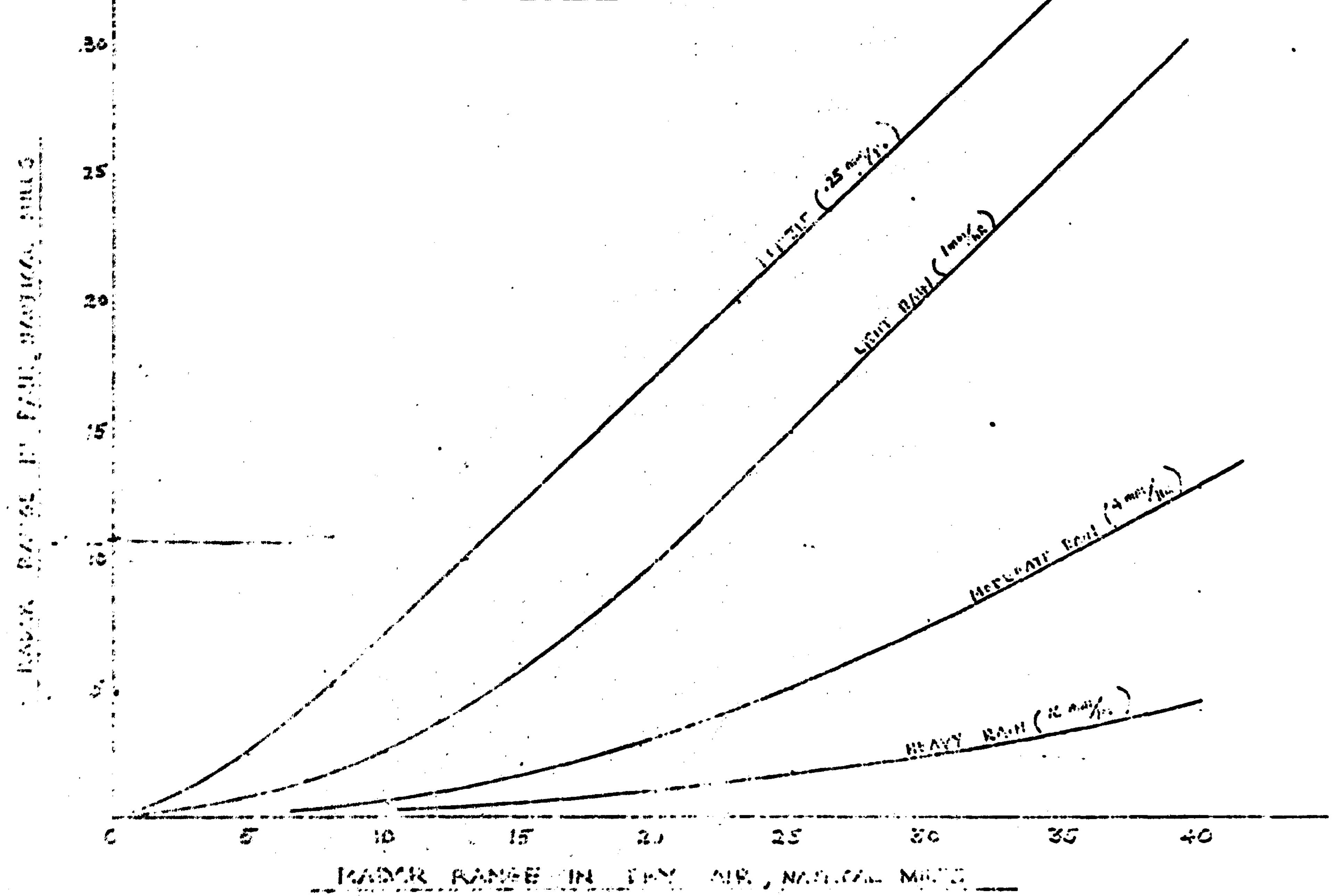
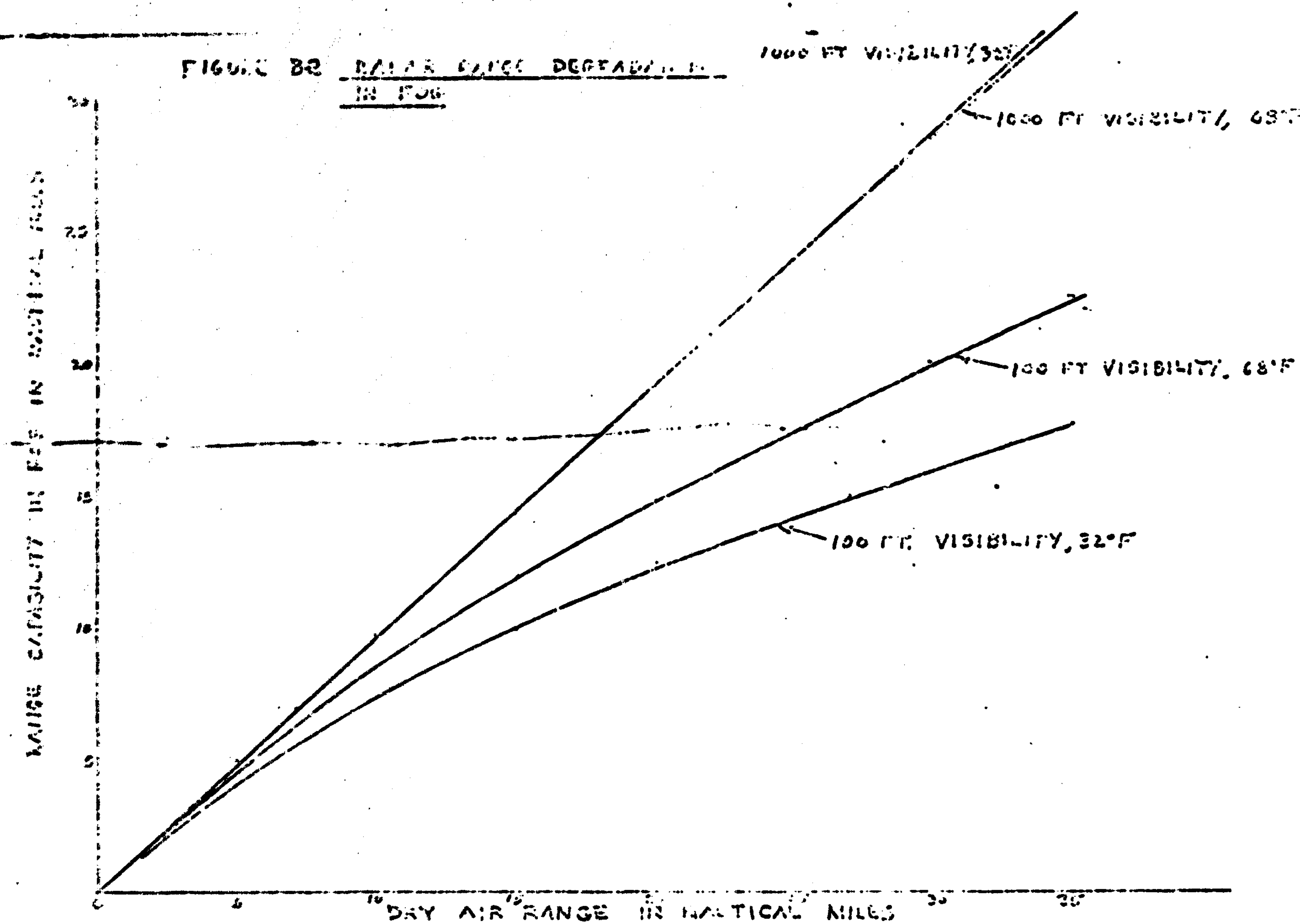


FIGURE 82 RADAR RANGE DEGRADATION IN FOG



As shown in the figure, the radar range capability in moderate rainfall rates (4 mm/hr.) can decrease by a factor of 10 over a dry environment.

In a fog environment, the scattering effect is negligible and the radar range attenuation stems primarily from attenuation caused by absorption. Figure B-2 presents the range degradation of the radar in terms of visibility at specific temperatures. As shown in the figure, range degradation becomes appreciable only under conditions of intense fog. Snow and ice weather environments can be expected to have similar reductions in range as rainfall.

To arrive at an estimate of the percentage of time significant radar performance degradation can be expected, meteorological weather data for the New York area was obtained from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service. Table B-1 presents meteorological data for the 1970 year as well as normals, means and extremes. As shown in the table, the mean number of days in which a precipitation rate of 0.01 inches or more was measured is 121. This is comparable to the number of days in the Washington, D.C. area measured by the same criteria, and information contained in the above reference will provide a basis for estimating the percentage of time significant radar range degradation can be expected. Figure B-3 extracted from the above reference shows the hours per year that a given precipitation rate was exceeded. Taking a performance degradation corresponding to light rain (1 mm/hr. ≅ .04 in/hr.) as being significant, the hours per year that .04 in/hr. can be expected are approximately 270. For an 8760 hours year period, the per-

TABLE B-1 METEOROLOGICAL DATA FOR THE CURRENT YEAR

Station: NEW YORK, NEW YORK — CENTRAL PARK OBSERVATORY — Standard time used: EASTERN — Latitude: 40° 47' N — Longitude: 73° 58' W — Elevation (ground): 132 feet — Year: 1970

Month	Temp. avg. daily maximum	Temp. avg. daily minimum	Temp. avg. monthly	Extremes highest	Date	Extremes lowest	Date	Degree days heating	Degree days cooling	Precip. total	Greatest in 24 hrs.	Date	Snow, ice pellets total	Greatest in 24 hrs.	Date	Rel. hum. 01	Rel. hum. 07	Rel. hum. 13	Rel. hum. 19	Wind
JAN	31.8	18.7	25.1	56	29	3	9	1227	0	0.88	0.28	30-31	6.4	3.0	30-31	73	[illegible]	64	66	[illegible]
FEB	40.7	25.3	33.0	57	22	5	20	890	0	4.08	2.63	19	9.4	3.4	18-19	67	76	58	63	[illegible]
MAR	45.3	32.0	38.7	56	23	20	10	800	0	4.18	1.67	20	4.0	4.0	20	61	[illegible]	49	54	[illegible]
APR	63.8	45.6	54.1	86	20	31	11	367	0	3.48	1.00	1-2	T	T	2	68	70	49	56	[illegible]
MAY	73.9	54.6	64.2	93	16	36	1	109	60	3.34	0.92	26	0.0	0.0		70	[illegible]	55	63	[illegible]
JUN	78.8	62.4	70.6	91	11	57	8	6	190	4.37	0.88	18	0.0	0.0		73	[illegible]	57	61	[illegible]
JUL	84.7	69.8	77.1	96	24	63	0	0	369	3.19	1.18	10-11	0.0	0.0		70	72	53	62	[illegible]
AUG	85.3	68.9	77.0	94	15	62	25	0	396	2.07	1.08	23	0.0	0.0		68	69	63	55	[illegible]
SEP	75.3	62.0	70.0	94	22	47	30	27	207	1.76	0.61	27	0.0	0.0		72	73	52	62	[illegible]
OCT	64.8	51.0	58.9	80	3	36	17	216	36	3.08	1.19	18	0.0	0.0		75	78	56	65	[illegible]
NOV	54.2	42.0	48.5	67	3	21	24	490	0	5.16	1.09	12-13	0.0	0.0		79	76	62	70	[illegible]
DEC	39.0	29.4	34.6	60	2	17	0	940	0	2.02	1.04	16-17	4.6	3.1	21-22	78	70	62	67	[illegible]
YEAR	61.7	46.6	54.3	96	SEP. 22+	3	JAN. 9	5090	1304	38.29	2.63	FEB. 19	21.2	4.0	MAR. 20	71	73	55	63	[illegible]

NORMALS, MEANS, AND EXTREMES

Month	Temperature, precipitation, relative humidity, wind, sunshine, sky cover and mean number of days
(a)	[illegible]
J	[illegible]
F	[illegible]
M	[illegible]
A	[illegible]
M	[illegible]
J	[illegible]
J	[illegible]
A	[illegible]
S	[illegible]
O	[illegible]
N	[illegible]
D	[illegible]
YR	[illegible]

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Maximum monthly snowfall 37.9 inches in February 1894; fastest mile of wind 113 from the SE in October 1954.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record. (b) Climatological standard normals (1931-1960). [illegible]

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F., precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. [illegible]

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North. [illegible]

To 8 compass points only.

NOT REPRODUCIBLE

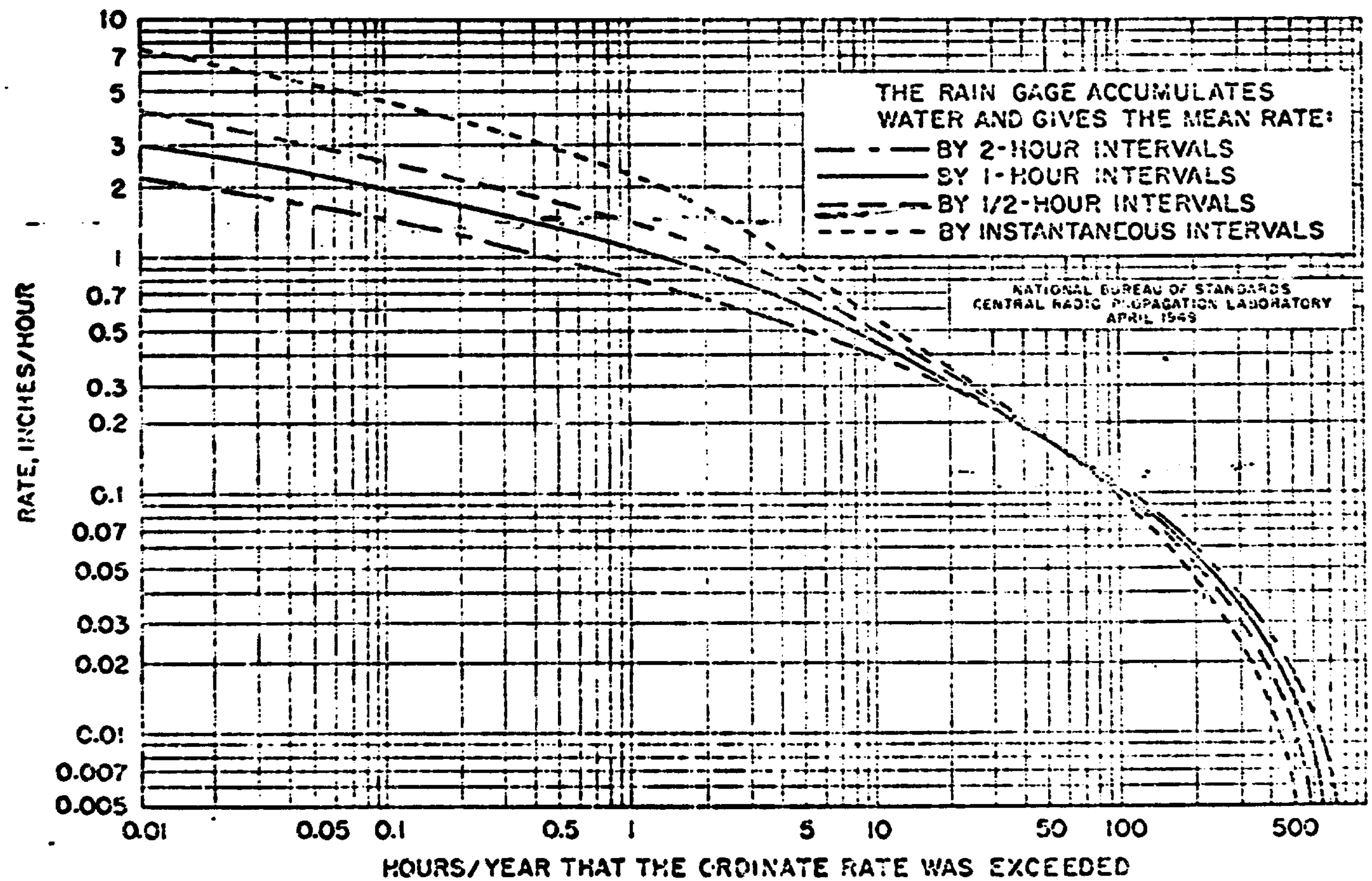


Fig. B-3. Cumulative distribution for point rates at Washington, D. C. The one-hour curve is based upon observed long-time data. The other three curves are not actually observed but are computed or derived from the one-hour curve

centage of time that performance degradation (corresponding to the light rain condition of Figure B-1) results is approximately 3.1%. This percentage is utilized in section 10.0 in analyzing candidate 2.

B-2 OMEGA, LORAN AND DECCA

In the utilization of electromagnetic wave propagation for radio navigation, consideration must be given to the effects of weather environment on operational reliability. In free space, all radio waves, regardless of frequency, are propagated in straight lines at the speed of light. Along the earth surface, however, propagation is generally categorized as either ground wave or skywave depending on frequency. Up to about 3 MHz, considerable transmitted energy follows the curvature of the earth (ground wave) whereas at frequencies up to 30 MHz, appreciable energy is reflected from the ionosphere (skywave). Since the ionosphere layer caused by radiation from the sun varies depending on the time of day, season and the 11-year sunspot cycle, the transmission path is unpredictable and hence skywave propagation is seldom used for navigation systems; its use is almost exclusively confined to ground-base direction finder systems. Ionospheric wave reflection, unfortunately, also affects ground wave systems. The ground wave signal is contaminated by skywave energy that arrives at a receiver by a devious path and special treatment is required to isolate the two. It should be noted that the skywave signal strength can be greater than the ground wave which further aggravates the problem. Skywave contamination is controllable in systems where pulse transmissions are used since the

edge of the ground wave arrives sooner than the skywave and hence the two waves are discernible.

The propagation of ground waves depends on the conductivity and dielectric constant of the earth surface and therefore differs, for example, for salt water and ground. While the free space power received varies as the inverse square of distance, the received power using ground waves varies as the inverse fourth power of range and depends on operating frequencies. Figure B-4 shows the ground wave field intensity as a function of distance for various frequencies over sea water. As shown in this figure, ground wave attenuation at 100 miles for an operating frequency of 150 KHz is 40 db whereas at 2000 KHz, the attenuation is 44 db. At greater distances, the affect of frequency is more significant.

The major weather influence on radio navigation systems is thunderstorm activity which results in so-called atmospheric noise. For frequencies below 20 MHz, the useful sensitivity of a radio receiver is limited principally by the atmospheric noise level of which the most important generator is lightning discharge. It is estimated that about 50,000 thunderstorms occur each day throughout the world and that, on the average, about 2000 are in progress at any one moment. Atmospheric noise power at the input to a receiver depends on frequency. Figure B-5 presents the frequency distribution atmospheric noise for both night-time and day-time operation. As shown in the figure, the atmospheric noise input at 10 KHz is approximately 10,000 times greater than at 10 MHz and varies significantly from day-time to night-time. Thus, in evaluating the weather environment on the performance of system candidates, it was necessary to provide an estimate of the percentage of

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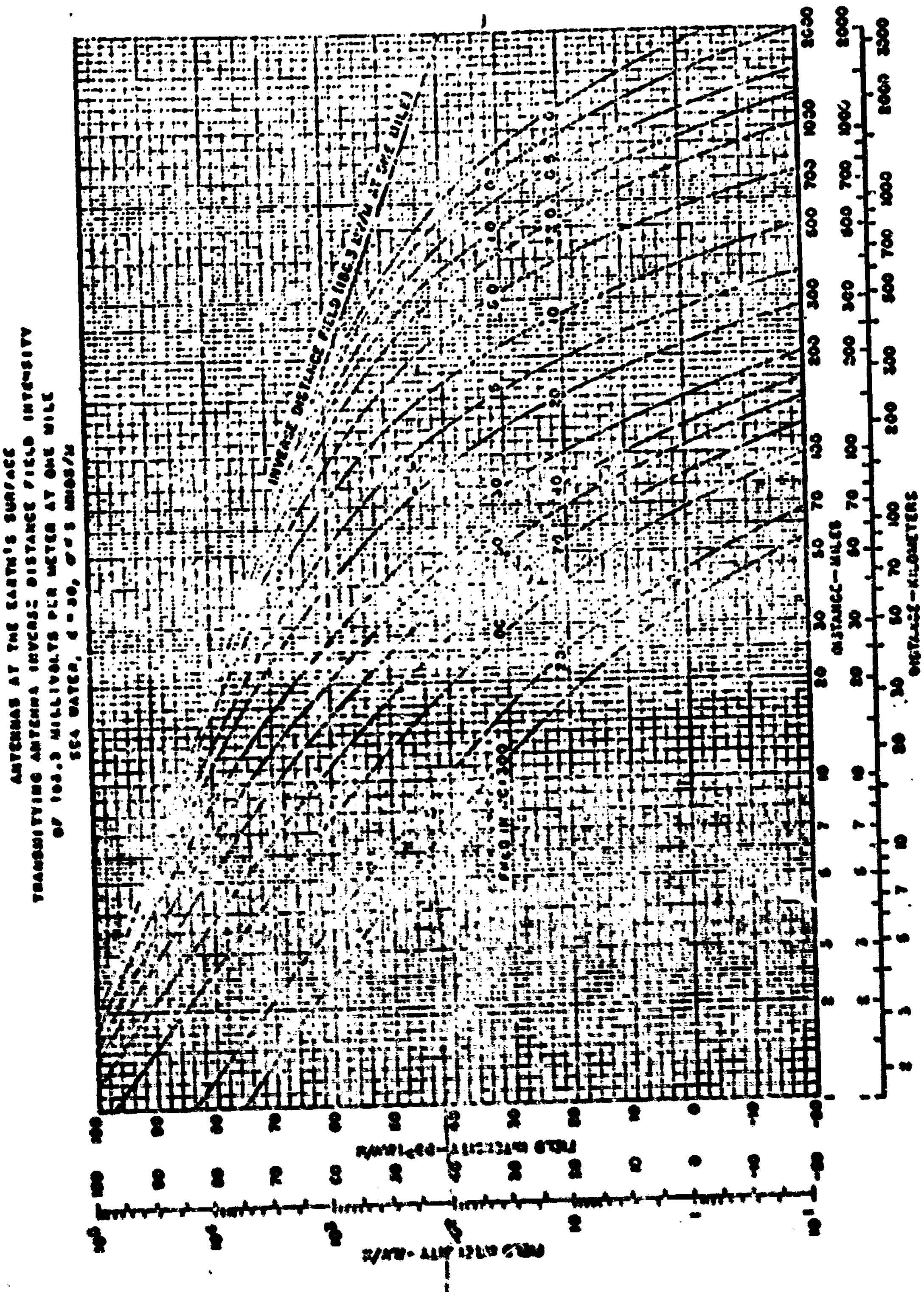


Figure B-4. Ground-Wave Field Intensity Versus Distance Curves for Various Frequencies in mc, for Vertical Polarization, 1-2,000 miles--Sea Water

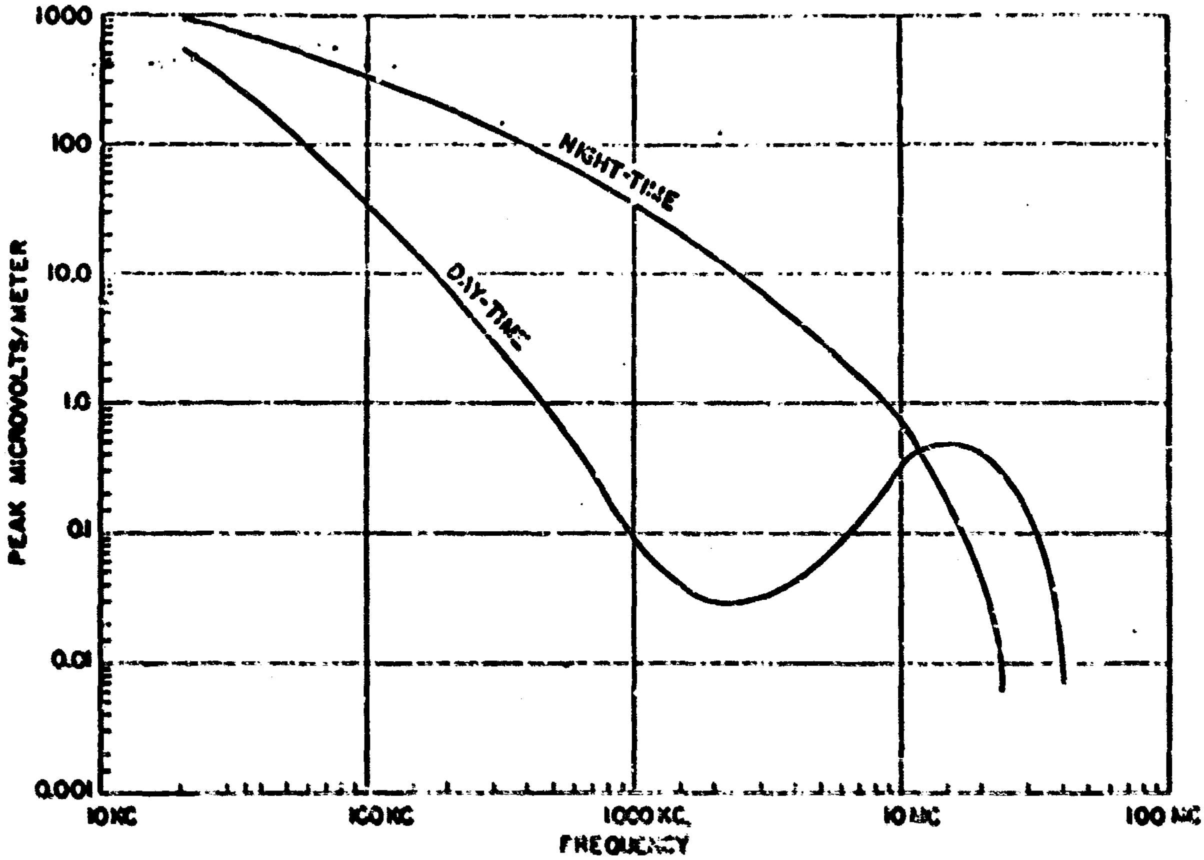


Fig.B-5. Frequency Distribution Atmospheric Noise (Median Values)

time atmospheric noise would affect the radio navigation systems utilized for the various candidates. From Table B-1, the mean number of days per year for thunderstorm activity in New York is 18. If it is assumed that the thunderstorm in the New York Bight area prevents reliable transmission for a period of 8 hours, the percentage of time performance degradation results is 1.6%.

From Figure B-5 it is apparent that Loran A, which operates at a 2 MHz frequency, will be more reliable than either Loran C (100 KHz), Decca (70-127 KHz) or Omega (10 KHz). Thus, in the evaluation of the candidate systems, several of the ratings were estimated to reflect the above considerations.

B-3 RADIO DATA LINK

In several of the candidate systems, the onboard vessel information is data linked to a shore station or center for data processing, assimilation, and recording. In these systems the operational reliability of the link is of extreme importance since the entire history of the vessel dump mission is predicated on the data being transmitted from the vessel and received at the shore center. The influence of weather environment on the data link essentially involves the electromagnetic wave propagation considerations discussed in B-2 but is more critical due to typically lower power availability aboard the dump vessel to transmit data link signals. In addition, the data content is contained on the received signal which must be processed to extract the information, thereby resulting in some signal loss, and is more sensitive to receiver input noise. Thus, the operational reliability of a

data link system is somewhat less reliable than the vessel location navigational systems discussed briefly in B-2.

The data link, if used for transmission of dump signal status from the barge to the towing vessel would utilize an operating frequency in the VHF band since the transmission path is in the order of 1200 yards and line-of-sight limitation is not a problem. Required transmitting power at this short range is minimal and estimated to be on the order of several hundred milliwatts. For the vessel to shore data link, however, line-of-sight frequencies cannot be used and operating frequencies in the MF or HF band would be required for transmission of signals at a distance 100 nm from shore.

B-4 SSMD TESTS ON AUTOMATIC TRACKING LORAN RECEIVER

During the study, SSMD performed tests on a Nelco Autofix 500 Loran receiver manufactured by the Nautical Electronics Company of Baltimore, Maryland. These tests were made to determine the operational difficulty in acquiring and locking on both Loran A and Loran C signals, and the capability of the receiver to automatically track signals in the New York harbor area.

Two Nelco receivers were installed in a station wagon by Nelco for Sperry, and a simple whip antenna used for signal detection. The station wagon was driven to various piers and docks along Manhattan and Loran A, (Loran C at times), time difference signals were recorded as well as signal to noise ratios at critical locations. The results of the experiment are summarized by the following remarks.

- Operational procedures to acquire and lock on Loran A signals is relatively simple with the Nelco Autofix 500 receiver. Loran C acquisition is somewhat more difficult due to signal strength of the Dana Air Force Station slave and noise levels in the Manhattan area.
- The Nelco receiver showed excellent tracking capability except under low bridges and tunnels where the signal was lost. This was not unexpected since normal radio broadcast signals are lost under similar circumstances.
- At all docks and piers where checks were made, acquisition and lock-on of signals was successfully demonstrated.
- Either Loran A or Loran C could be utilized as a vessel location subsystem for the DMS; Loran A is preferred, however, due to the relative ease of acquiring and locking on of the Loran A signals.

APPENDIX C

DESCRIPTION OF VESSEL LOCATING METHODS

C-1 HYPERBOLIC SYSTEMS

The hyperbolic navigation systems considered in the study include Omega, Differential Omega, Loran C, Loran A and Decca. The subsections following briefly describe the fundamental operating characteristics of these systems and, in particular, factors relevant to utilization of the systems for the DMS.

C-1.1 Omega

Omega is a long range radio navigation system utilizing phase difference measurements of 10.2 KHz carrier frequencies received from each of two stations whose transmissions are phased synchronized. Hyperbolic lines-of-positions of constant phase difference with the stations lying at the foci of the hyperboles provide a position fix at the intersection of the two lines-of-position. The accuracy of the fix is proportional to the LOP angles of intersections, 90° being optimum. Characteristic of CW phase measuring systems, cyclic ambiguity causes isophases LOPs or lanes every 8 nm. To increase the lane ambiguity, the stations cyclically transmit the CW waves at several frequencies; i.e., 10.2 KHz, 13.6 KHz and 11.33 KHz, with a 0.2 sec. off period between each transmission. With a two frequency receiver, the resolution or lane ambiguity increases to 24 nm and with a three frequency receiver improves to 72 nm. Generally, with some minimal dead reckoning navigation equipment aboard the vessel, lane ambiguity is easily resolved. A typical functional block diagram of an Omega navigation receiver is shown in Figure C-1.

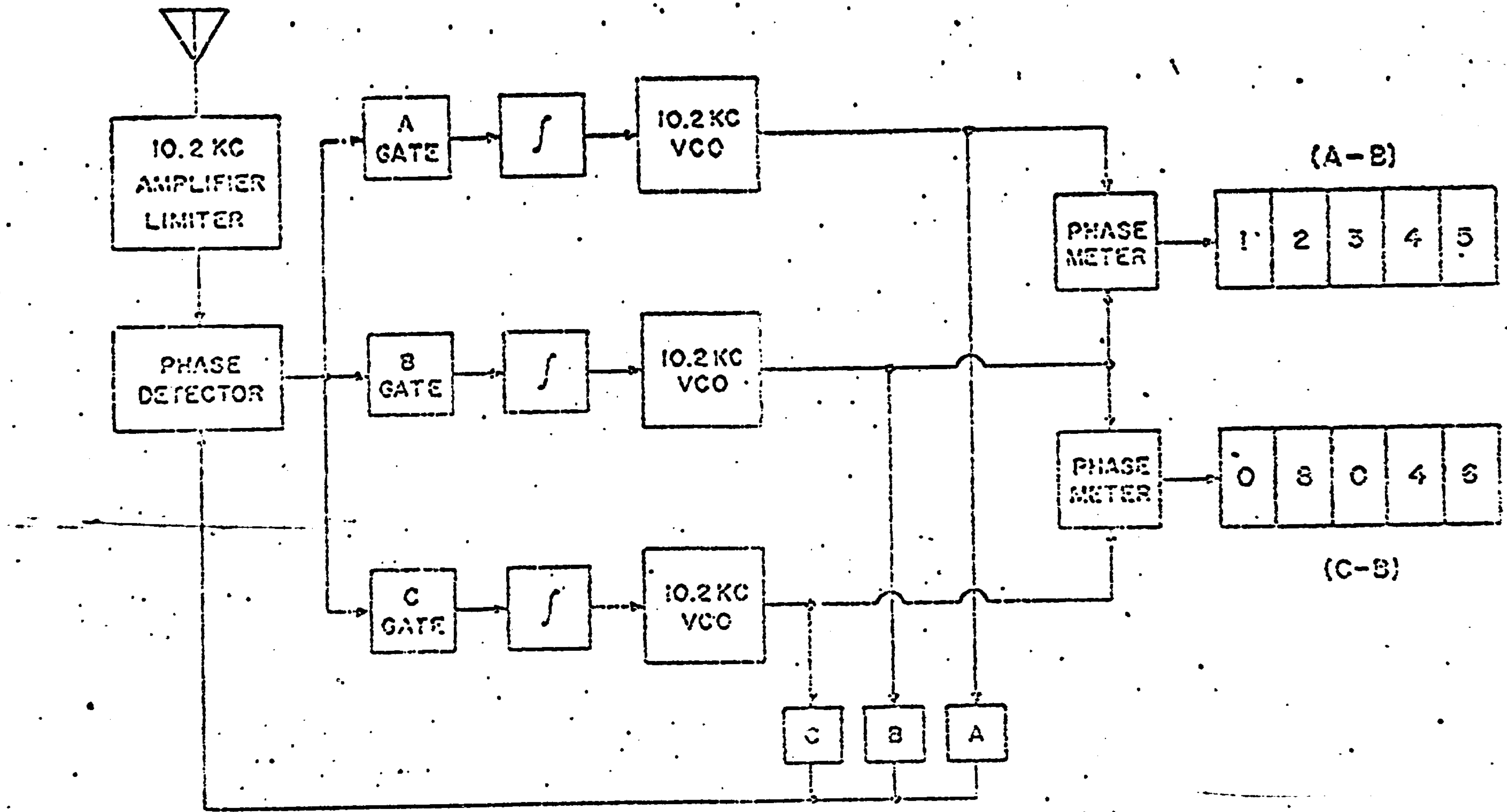


FIGURE C-1 FUNCTIONAL BLOCK DIAGRAM OF AN OMEGA NAVIGATION RECEIVER

As discussed in Appendix B, the propagation of Omega signals conforms to the earth-ionosphere wave guide which has a diurnally varying dimension along the propagation path. This variation in ionospheric height produces an effective variation in propagation velocity which must be compensated for as a function of time and approximate position to assure predictable phase comparison. The variation predictions, known as skywave corrections, have been tabulated based on a prediction model as a function of time and day for specific locations. Results of measurement programs have shown an operational accuracy of 1-2 nm RMS depending on time of day. Improved accuracy is possible using the Differential Omega approach discussed in some detail in section C-1.2.

C-1.2 Differential Omega

In the Differential Omega concept, a remote Omega receiver at a known geographic location is utilized to correct certain unpredictable propagation anomalies, thereby resulting in improved fix accuracy. It is assumed that the Omega receiver used for position fixing is experiencing the same unpredictable variations as the remote Omega receiver at the known location and hence suitable corrections may be determined and applied to correct the data measured by the actual navigational receiver. This approach removes time dependent errors and increases accuracy repeatability to approach the relative accuracy of the two receivers operating in a simultaneous environment. Experimental data obtained with Differential Omega shows an improvement of 4:1 over a conventional Omega system with average LOP errors of 4-7 centicycles at night and 1-3 centicycles during the day (1 centicycle

equals approximately 1 microsecond which is 150 meters on the baseline). Thus, the Differential Omega concept is recommended over Omega for use as a DMS vessel location subsystem for the small cost of an additional remote shore based receiver.

C-1.3 Loran C

Loran C utilizes ground waves at somewhat higher frequency (100 KHz) than Omega but still provides long range coverage (approximately 1000 nm). The concept used in Loran C is the measurement of the line of arrival of pulses transmitted from two stations which generates hyperbolic lines of equal time difference with the foci located at the stations. To obtain a position fix, two LOPs are required and thus three stations (one master and two slaves) are necessary. Unlike Omega, the use of pulse transmission rather than CW transmission provides a means of discerning the skywave from the ground wave. Skywave contamination can be expected starting at 30 μsec from the start of the pulse, and hence with Loran C only the first three cycles are used by the receiver. Fine time difference measurements are accomplished by phase difference measurements of the carrier frequencies with ambiguity avoided by the coarse time difference measurement.

All Loran C transmitters operate at a frequency within the 90-110 KHz band. The master station transmits its pulses in groups of nine at a repetition rate of 10 to 25 groups per second. There are five basic rates each having eight specific rates. Spacing between pulses in the group is 1000 usec. After the master transmits its pulses, a slave station transmits an eight pulse group also spaced

1000 usec. The time between master and slave transmission is at least equal to the one-way time from master to slave plus an additional 2000 μsec to allow the skywave to die down. Still later, the next slave transmits its eight pulses. The use of a train of pulses increases the average power transmitted similar to the use of pulse compression in radar. Each pulse within a group may have its RF cycles in phase or 180° out of phase with an established reference, thereby providing identification of station chains, and serves as a communication between stations.

Because of atmospheric noise which, when viewed over the 20 KHz receiver bandwidth, is 20 db higher coupled with as much as 120 db difference in signal strengths between station and perhaps 35 db of interference signals, the Loran C receiver requires a very high effective selectivity, and filtering using electromechanical or digital servo loops with slow speeds and long integration times ($\sim$ 10 sec.) is required. Initial search and acquisition of the signal may take up to 10 minutes.

The chief parameters affecting Loran C accuracy are stability of propagation and the crossing angle of the hyperbolic LOPs. Although propagation variations of up to 0.4 μsec have been observed, they can be partly compensated and propagation errors seldom exceed 0.1 μsec. In the Eastern U.S. chain, considerable data has been obtained at stations showing an error radius of 800 ft. for 95% annual average.

C-1.4 Loran A

Loran A is similar in operational concept to Loran C but utilizes higher operating frequencies (approximately 2 MHz). This higher frequency limits its operational range and Loran A is utilized primarily for marine navigation near shore. The system utilizes a master and two slaves; the slaves normally about 200 miles from the master. To distinguish various chains from each other, three carrier frequencies are used: 1850, 1900 and 1950 KHz. (Twenty-four sets of pulse repetition rates with half-amplitude pulse durations of 40 μsec with a 21 μsec rise time). The master transmitted pulses are received by the slave station and, after a fixed time delay, are retransmitted. The differential delay between the reception of the master and slave pulses provides a line-of-position, two LOPs required for a fix. The accuracy of Loran A depends, as with Loran C and Omega, on the hyperbolic LOPs crossing angle, as well as the accuracy of pulse-time matching in the receiver and slave repetition accuracy. Total measurement error is on the order of 1.5 μsec. Along the base line between stations accuracy is on the order of 1000 ft. whereas at extreme ranges (~800 nm) and at right angles to the base line, it is on the order of 0.5 nm.

C-1.5 Decca

The British developed Decca system is a hyperbolic radio navigation system which utilizes low frequency (70 to 130 KHz) CW transmission signals from a master and three slave stations to provide a position fix. Each station transmits a stable CW frequency signal that bears a fixed relationship to the frequencies of the other three stations.

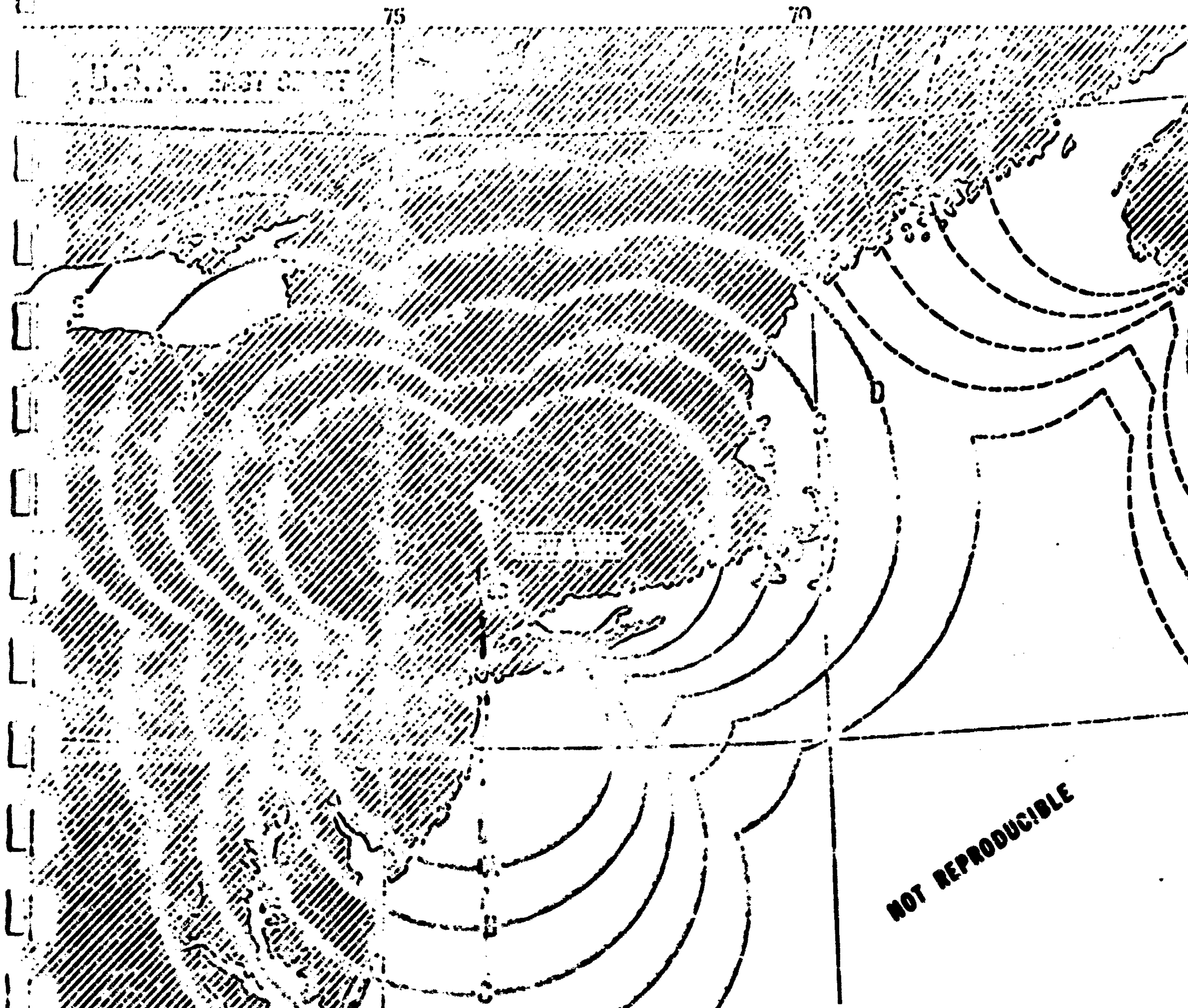
Phase comparison of the signals produces hyperbolic LOP where the phases are equal. Typical frequencies transmitted would be as follows:

Master Station:	85 KHz (6 f)
Red Slave Station:	113.333 (8 f)
Green Slave Station:	127.500 (9 f)
Purple Slave Station:	70.833 (5 f)

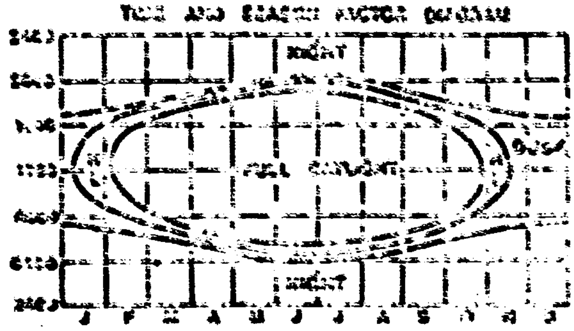
These frequencies are multiples of frequency f which in this case is 14.166 KHz. The receiver incoming frequency signals are multiplied by factors to produce frequency differences for the stations which are either 30 f (Purple), 18 f (Green) or 24 f (Red). These differences are measured by a phase meter of the continuously integrating type (decometer) which indicates total and fractions of cycle that the receiver passed through. Instrument accuracy is on the order of 1/50 of a lane corresponding to 5 yards along the baseline.

The Decca system utilizes a lane identification technique for solution of the lane ambiguity problem. Each station transmits, in addition to its fine fixing signal, a lane identification signal by a second transmitter at specified intervals. This technique, coupled with a comparison of the f frequency for each of the three phase comparison systems for half a second, reduces lane ambiguity to 1/100 of a lane.

Practical coverage for Decca is limited to about 200 nm because of continuous wave propagation and skywave contamination. Figure C-2 presents accuracy contours of Decca for the USA East coast as a function of season and time for 95% probability of fix accuracies.



DECCA PERIOD (see season diagram)	A	B	C	D	E
WINTER NIGHT	[illegible]	3	x	x	x
SUMMER NIGHT	1	2	4	x	x
DUSK	½	1	2	4	8
HALF LIGHT	¼	½	1	2	4
FULL DAYLIGHT	[illegible]	¼	½	1	2



Notes:

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible] = HALF LIGHT on time and season factor diagram.

Figure C-2 ACCURACY CONTOURS OF DECCA

C-2 RDF

The use of ground based radio direction finders for fix locations has been utilized for many years and its application to the DMS is a natural consideration. In this system, transmissions from the vessel are received at two shore RDF stations from which bearings to the vessels are measured; the two bearings uniquely fix vessel location. The basic principle of direction finding (DF) is the measurement of differential distance to the transmitter using a loop or Adcock type antenna. Currents generated in each vertical segment of the loop induced by vertically polarized transmissions, when equal in amplitude and phase, result when the loop is 90° to the direction of the arrived signal. While many types of RDF antennas are in use, the Adcock type is perhaps most attractive for a shore-based RDF station. In its simplest form, this antenna consists of two vertical antennas connected to a receiver. Operation is similar to the loop antenna, the null indicating signal direction. Due to the size of antennas utilized in the 400 KC to 3 MHz range, physical rotation of the antenna is not practical and a goniometer in conjunction with four or eight antenna towers is used. The goniometer is an instrument consisting of two sets of windings at right angles to each other with a central rotor which in effect translates the received radio field at the antennas into a miniature magnetic field in which the rotor operates. The angle output of the goniometer rotor then provides the direction of the transmitted signal.

Accuracy of an RDF system depends not only on instrumentation errors but also on external error factors such as phase interference

effects, polarization errors, tilt of the ionospheric layer, and site irregularities. In a modern RDF system such as the Marconi S480, bearing accuracies of ±1 degree, 1.5° with calibration corrections are possible. At night with skywave contamination, however, accuracy may reach 2° at 100 nm and as much as 4° at 500 nm.

C-3 RADAR

Vessel location using a shore-based radar is determined from the time elapsed between transmission and reception of a radar signal (range) and the radar beam antenna directivity (bearing). The operating principles of a radar in its simplest form utilize a transmitter which generates high power, short duration pulses which are radiated in a narrow beam by a parabolic reflector which is rotated in azimuth. When the pulses strike the target, a small amount of power is radiated back to the antenna which is amplified in a receiver. The receiver output is displayed on a PPI indicator; the radial scan is generated in synchronism with the transmitted pulse rate and a rotary scan with the azimuth rotational rate. This causes a spot to be illuminated on the PPI in which the distance and azimuth are proportional to the true position of the target.

When the target is cooperative as in the case of the DMS vessel, a secondary radar (radar beacon transponder) can be used which reduces power requirements of the radar transmitter and reduces clutter by utilizing different frequencies. Modulation techniques can be incorporated on the beacon to provide vessel identification and other coded data.

The frequency of radar operation varies depending on range, environment used and accuracy required. Generally radar range accuracy, which is primarily a function of pulse duration and display resolution, is on the order of 1000 ft. and bearing accuracy, which depends on azimuth beam width, less than 1°. Because of the high operating frequencies of radar systems, line-of-sight limitations prevent range coverage out to 100 nm.

Appendix D

Equipment Specification

for

Sea Dump Monitoring System

GB-13-1123 (NP)

15 July 1971

SPERRY RAND
SYSTEMS MANAGEMENT DIVISION

EQUIPMENT SPECIFICATION
APPROVAL RECORD

EQUIPMENT SPECIFICATION
FOR
SEA DUMP MONITORING
SYSTEM (DMS)

APPROVALS

NAME	DATE	POSITION
P. Bizzigotti	7/15/71	Research Section Head
J. Charlton	7/15/71	Program Manager

SPECIFICATION NUMBER AND DATE	CODE IDENT NO. 15001	
GB-13-1123 (NP)		PAGE 1 OF 17

SM 549-2

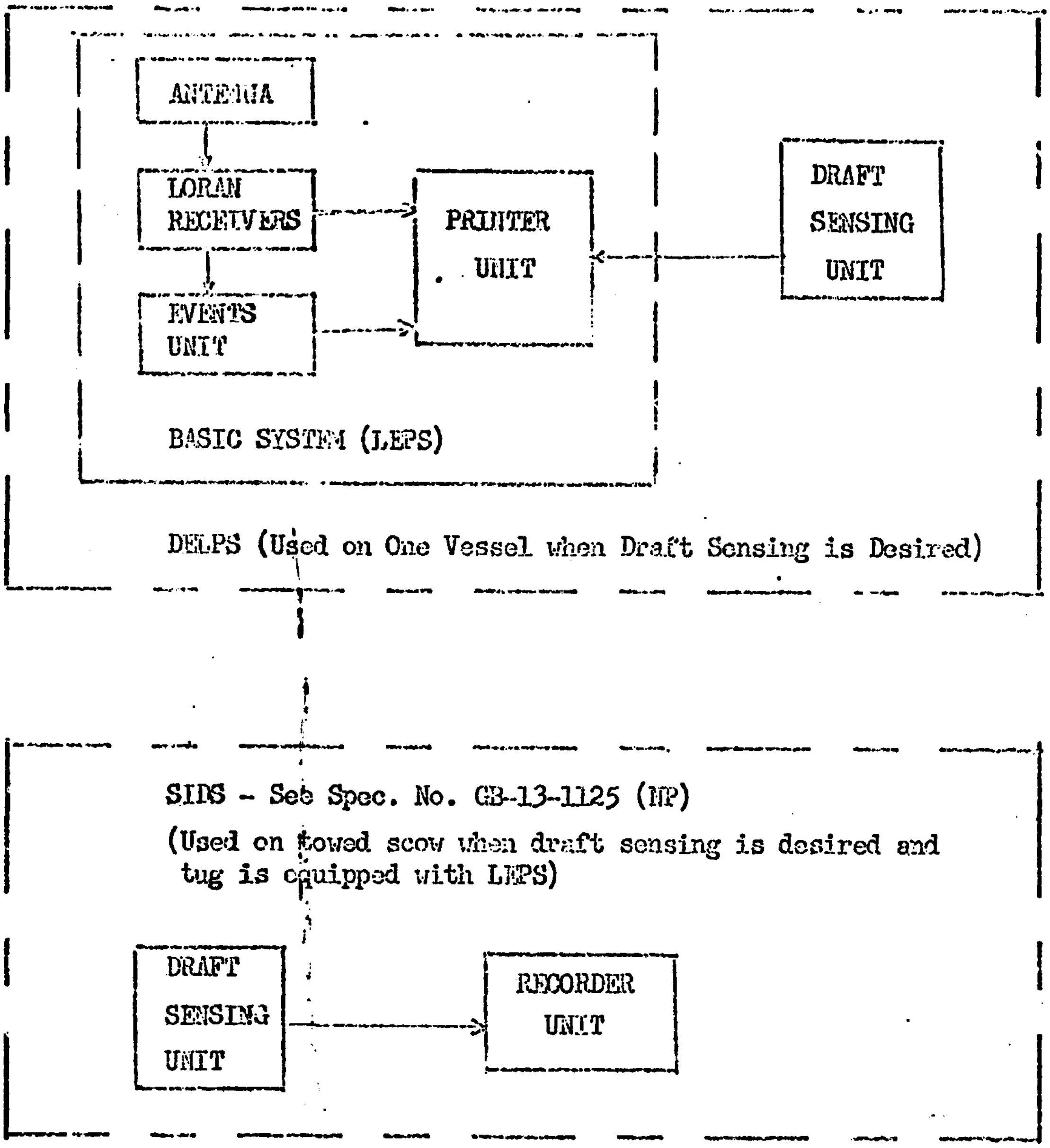


Figure 1 - DMS System Block Diagram

LINE NO.

3.1.3 Functional Flow Diagram and Interface Signals

The system functional flow diagram and the system electrical interface signals shall be as specified in Figure 2 and Table 1, respectively.

3.1.4 Physical Arrangement and Major Components

The following is a list of the eight major components of the DMS. With the exception of the antenna and coupler, all equipment shall be mounted in one rack-and-panel type case, Unit Designation (UD) 108 or 108A. The only interface between this case and the ship shall be power input.

UD	COMPONENT	QTY/ SYSTEM	APPROX. SIZE	DESCRIPTION
101	ANTENNA	1	15+ Ft.	VERTICAL WHIP
102,103	LORAN RCVR	2	14"x9"x12"	NELCO AUTO-FIX 500 MODIFIED
104	PRINTER UNIT	1	9"x6"x18"	NEWPORT LABS 800 MODIFIED OR MONSANTO MODEL 511A MOD.
105	EVENTS UNIT	1	9"x5"x10"	SSMD CUSTOM DESIGN
106	EQPT. RACK	1	26"x19"x20"	SSMD CUSTOM DESIGN
OR,	OPTION 1 (for use where less floor/bench space is available):			
106A	EQPT. RACK	1	16"x32"x20"	SSMD CUSTOM DESIGN
PLUS,	OPTION 2 (for use when positive dump sensing is desired):			
107	DRAFT SENSING UNIT	1	10"x5"x17"	SSMD CUSTOM DESIGN

LINE NO.

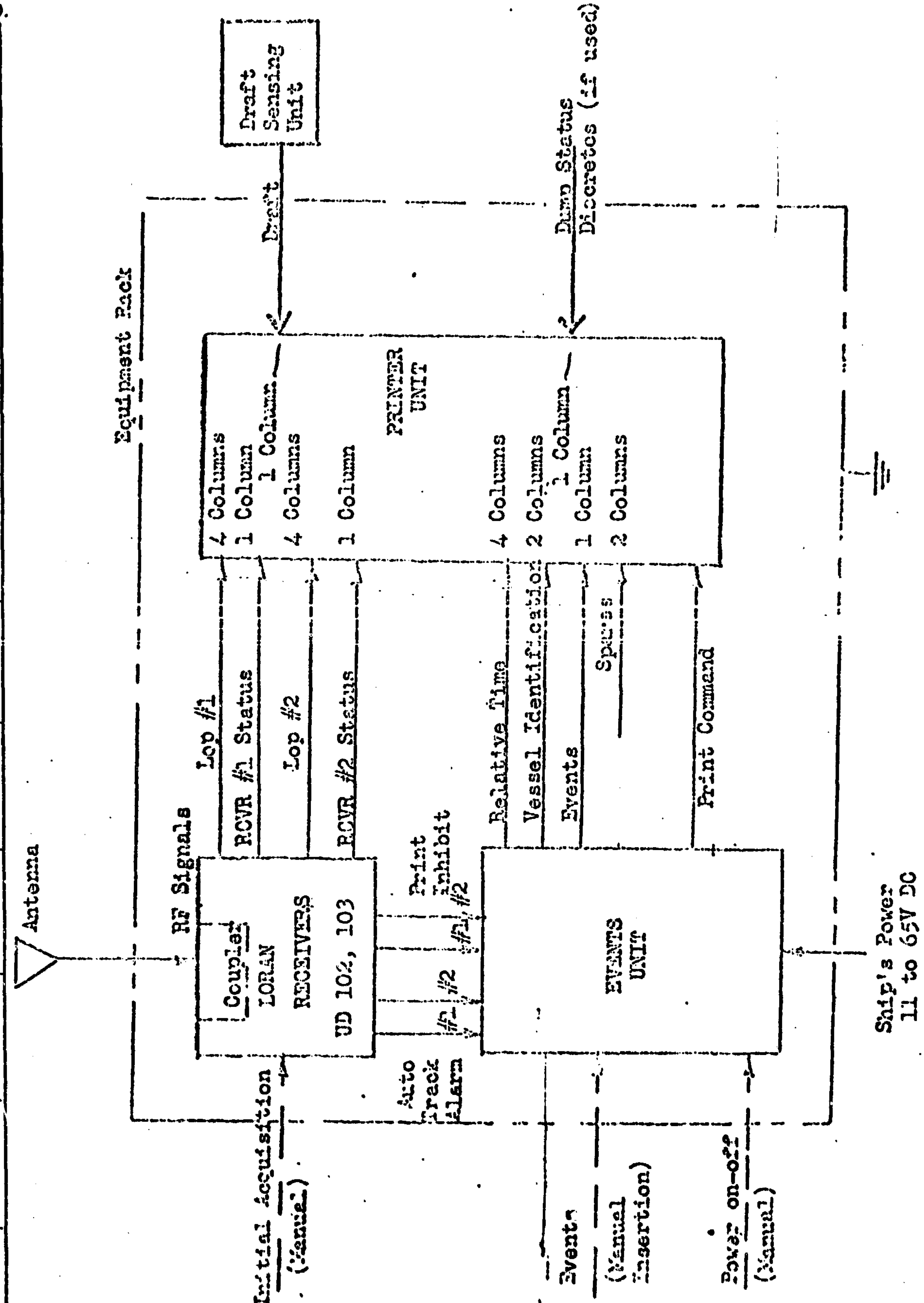


Figure 2 - DMS Functional Flow Diagram

From	To	Function	Signal Characteristic
Ant/Coupler	Loran Receivers	Loran Station Signals	RF, 1 uv to .1v
Loran Rcvr #1	Printer Unit	Loran Line of Position #1	BCD, 4-wires each of 4 columns
"	"	Operating Status Loran Rcvr. #1	BCD, 1-wire "0" = Inoperable
"	Events Unit	AutoTrack Alarm	BCD, 1 wire, 1 = Loss of Automatic Track
"	"	Print Inhibit	BCD, 1 wire, = Inhibit
Loran Rcvr. #2	Printer Unit	Loran LOP #2	BCD, 4 wires Each of 4 Columns
"	"	Operating Status Lor. Rcvr #2	BCD, 1 wire, "0" = Inoperable
"	Events Unit	Auto Track Alarm	BCD, 1 wire "1" = Loss of Automatic Track
"	"	Print Inhibit	BCD, 1 wire, "1"= Inhibit
Events Unit	Printer Unit	Elapsed Time	BCD, 24 hr., HHMM, 4 wires ea. of 4 col.
"	"	Vessel Ident.	BCD, Pre-Set, 4 wires ea. of 2 col.
"	"	Events	BCD, Coded, 4 wires, 1 Column
"	"	Print Command	BCD, "1" = Print

Note, All BCD Signals: "0" is - 1.0v to + 0.5V DC; "1" is +2.4v to + 7.0v DC

Draft Sensing Unit	Printer Unit	Draft Signals	Discrete switch closures at following fractional parts of full load: 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16, FULL.

TABLE 1

System Electrical Interface Signals

3.1.5 Detailed Features

3.1.5.1 Operating Modes

The following operational or status modes shall be provided:

- Power-off Mode
- Transit Mode
- Dump Mode
- Test Mode

3.1.5.1.1 Power-off Mode

The power off mode shall be the de-energized status of the DMS and shall be available for application when the system functions are not required or when malfunction, maintenance, shipment or other requirements necessitate withdrawal of power.

3.1.5.1.2 Transit Mode

The transit mode is the normal operating mode used enroute to and from the dump site. A maximum of ten minute warm up shall be required. Minimal crew operational participation shall be required in this mode and shall be limited to initialization settings and normal acquisition of Loran Master stations. In this mode, continuous monitoring of location of the vessel shall be provided by two autotracking Loran receivers, and shall be recorded at every six (6) minutes which will result in a history of the entire mission. In this mode, the operator shall be able to record significant events by depressing appropriate buttons on the events unit.

3.1.5.1.3 Dump Mode

The dump mode shall be initiated upon command by the vessel captain by depressing the "Dumping Now" events button to signify the initiation of dump and the "Dumping Completed" button to signify the completion of dump. Upon depression of these and any other "Events" buttons, the vessel location shall be recorded every 15 seconds for a two minute period.

3.1.5.1.4 Test Mode

The test mode shall commence following activations of the test mode switch and would be entered normally at dockside prior to and after return of a dump mission to ascertain proper equipment operation. As a minimum, this mode shall provide gross malfunction indications of the Loran receivers and various events buttons. An alarm shall be sounded and a light lit when the Loran receivers lose lock.

LINE NO.

3.1.5.2 Mode Sequence

Normal operational modeing sequence shall be as follows:

- Power-off mode
- Test mode
- Transit mode
- Dump mode
- Transit mode
- Test mode
- Power-off mode

3.1.5.3 Electrical Power

The DMS equipment shall be energized from the following ship power source:

- DC, Nominally 32V (11V to 50V), nominally 100 watts

3.1.5.4 Cooling Requirements

The DMS shall operate without need of external cooling or heating devices for the service conditions specified in paragraph

3.1.5.5 Data Transmission

The operating concept is based on the captain or other person in authority adding information to the recorded data such as type of waste, date and hour at the start and end of the dump trip, together with a signed statement that the data was not manipulated, and transmitting the record to the Corps of Engineers via U.S. Mails, showing a postmark no later than 12 hours after return to dock.

3.2 Characteristics

3.2.1 Performance Characteristics

The DMS shall provide the required functions within the required accuracies specified herein under any natural combinations of service conditions listed in paragraph 3.2.7 and following the normal operating sequenced presented in paragraph 3.1.5.2.

3.2.1.1 Dump Detection

The initiation of dump shall be indicated by depressing the "Dumping Now" onsite button. The completion of dump shall be indicated by depressing the "Dumping Complete" onsite button. In addition, when a Draft Sensing Unit is employed, vessel draft shall be measured to an accuracy of 2% of the draft setting of each switch, excluding any velocity error.

3.2.1.2 Vessel Location Accuracy

The system shall determine and record location of the vessel within the following performance limits.

Distance From Harbor	CEP Error, Vessel Location
10 N Mi	0.15 N Mi
100 N Mi	0.25 N Mi

3.2.2 Physical Characteristics

3.2.2.1 Total Weight and Size

The total weight and size of the DMS onboard equipments shall be consistent with good design practices for the intended application. Size and weight of major equipment shall be limited by the requirement for single man portability of an individual component, and shall be as specified in the detailed equipment specifications. The nominal system weight shall be 85 pounds. The maximum weight of a single installable unit shall not exceed 45#. The system rack case shall be nominally 26" wide x 19" high x 16" deep; or, under option 1 shall be nominally 16" wide x 32" high x 16" deep. The Draft Sensing Unit shall be nominally 10" wide x 5" high x 17" deep and nominally 30#.

3.2.2.2 Tamperproof

The system equipments shall, to the maximum extent practicable, provide security from unauthorized adjustment and/or tampering. Where desirable and practicable, suitable enclosures and fastening devices shall be provided to discourage abuse of equipments or willful modification of system function to defeat the intended purpose of the DMS.

3.2.2.3 System Installation and Interchangeability

The DMS shall be designed for easy installation aboard tugs and self-propelled dump vessels. The equipment rack would be located preferrably in the wheel house. The antenna would be located as high as shore antennas). The Draft Sensing Unit would be located below decks so that it stays below the water line and typically would be connected on the shipboard side of an existing sea cock in a sea water intake line. Although such installation may be customized, each major component and the entire rack shall be interchangeable with other similarly marked units without modification or adjustment of the equipment other than pre-set vessel identifiers and draft settings.

3.2.2.4 Portability

The DMS, especially the basic system LPS, shall be "portable" in the sense that system can be carried aboard a vessel upon short notice and requiring minimal or no vessel modification. When used in this way, the antenna may be clamped to existing vessel rails or

other suitable existing structure and the antenna cable routed through existing cableways, openings, etc. The only ships interface required shall be a properly fused and grounded power input connection to the equipment rack. The intent of this requirement is to permit use of the system on vessels only occasionally making a trip to the dump sites where it is not desired to perform a costly vessel modification to accept the equipment or to assign a system just for that vessel.

3.2.3 Reliability

3.2.3.1 Operational Life

The equipment shall have a minimum total operating life of 5000 hours without major overhaul but including normal servicing and replacement of parts. Servicing methods shall preserve and maintain the design MTBF.

3.2.3.2 Operational Stability

The equipment shall satisfy the requirements of this specifications continuously or intermittently for a period of at least 400 hours without necessity for any adjustments other than normal operation.

3.2.3.3 Reliability in Mean Time Between Failures

The equipment under normal operating environments shall have a mean time between failures (MTBF) of 400 hours.

3.2.4 Maintainability

Maintenance shall be based upon a concept of: only providing replacement of fuses, etc., at sea; normally replacing units (e.g., Events unit) dockside; normally replacing plug-in assemblies at a repair depot; and, replacing detailed parts and pieces at the depot or factory, as appropriate.

3.2.4.1 Equipment Maintainability

The RMS equipments shall have a Mean Time To Repair (MTTR) of 1.2 hours. The MTTR is defined herein as the average time to perform corrective maintenance action including:

- Average time to remove faulty equipment from vessel
- Average time to isolate a fault to a replaceable assembly or module at maintenance depot
- Average time to remove faulty assembly or module and replacement with a spare item
- Average checkout time to assure that the newly installed item is functioning properly (checkout of repair)
- Average time to reinstall equipment on vessel, and checkout system

The specified MTTR does not include logistics/administrative time for shipping or transporting the faulty equipment to and from the vessel.

3.2.4.2 Maintenance Man Hours per Operating Hour (M-MH/OH)

The DMS equipment average in maintenance man hours per operating hour shall not exceed 0.03.

3.2.4.3 Built-in Test Features

The equipment shall have built-in test features to record the status of each Loran receiver and to indicate the loss of automatic track of each Loran signal by sounding an alarm buzzer and lighting a flashing panel lamp. Similarly, an alarm shall be provided to indicate an impending loss of paper supply.

3.2.5 Availability

The DMS shall have a maximum downtime of 2 hours for dockside repair following announcement of a needed repair and arrival dockside of a trained maintenance man with spares and normal test equipment.

3.2.6 Service Ambient Conditions

The equipments shall operate satisfactorily under any of the environmental service conditions or reasonable combinations of these conditions as specified below.

3.2.6.1 Ambient Temperature

The DMS shall function in an ambient temperature environment of +35°F to +100°F without the requirement for external heating or cooling. The antenna shall function in an ambient of -20°F to +150°F.

3.2.6.2 Sea State

The DMS shall function in all sea state conditions up to Beaufort scale 8 (gale force winds of 40 Kts).

3.2.6.3 Relative Humidity

The DMS shall function properly at all relative humidities normally encountered in the salt-sea atmosphere.

3.2.6.4 Rain, Snow, Ice

The antenna shall function properly exposed to all normal rain, snow, and ice encountered at sea. (The remainder of the DMS is in the protection of the ship).

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3.2.7 Handling for Maintenance

Deployment and logistic support of the DMS will necessitate transporting of equipments to and from dockside from maintenance and spares depots, requiring a minimum number of personnel for handling, installation and removal from the vessel. The DMS shall be designed to permit one-man maintenance and transporting of system units.

3.3 Design and Construction

The design and construction of the DMS shall be in accordance with the following subparagraphs.

3.3.1 Materials, Processes, and Parts

In the selection of materials and parts for the DMS, fulfillment of the major objectives of the system shall be the prime consideration. Emphasis of the environmental and service conditions imposed on the equipments shall be a major consideration in the design and selection of system components. Materials and processes shall be utilized, where appropriate, which minimize deterioration and corrosion due to the salt-sea atmosphere.

3.3.1.1 Cabling and Connectors

The DMS equipments shall use cables and connectors to be specified by the contractor.

3.3.1.2 Standard Parts and Materials

The DMS equipments shall utilize, where feasible, standard commercial parts and materials. Non-standard parts including electronic tubes, diodes and transistors shall be permitted when component performance degradation or system reliability is significantly reduced by using standard parts.

3.3.2 Nameplates and Product Marking

Nameplates and product marking for equipment identification shall be in accordance with standards to be specified by contractor and will clearly show ownership of equipment by the Corps of Engineers.

3.3.3 Workmanship

Workmanship shall be of high quality to assure fulfillment of the design objective of the DMS. Military specification MIL-STD-454, requirement 9 shall serve as a guide in the design and procurement of parts and equipment which might largely follow best commercial practice.

LINE NO.

3.3.4 Interchangeability

The EMS equipments and component parts shall permit interchangeability with other manufactured or supplied designated equipment and parts unless stipulated differently by model, drawing changes or other information by contract or order. The interchange of units shall not significantly alter system performance or reliability.

3.3.5 Safety

The EMS design shall assure operational safety of the vessel crew and/or maintainance personnel. The electrical system shall provide suitable fusing and grounding of equipments to minimize electrical shock hazards. The equipment shall not exhaust any flamable, explosive, or toxic gas during normal operation or at elevated temperatures up to 250°F ambient.

3.4 Documentation

Documentation requirements, if any, shall be as specified in the contract.

3.5 Logistics

3.5.1 Maintenance Philosophy

The system shall be designed to require minimum maintenance and adjustment over its service life. Maintenance shall be performed on a unit modular level at designated maintenance depots and/or equipment manufacturer facilities. Shipboard maintenance at dockside shall be considered only to the extent of replacement of fuses, adjustments, and replacement of separately installable units.

3.5.2 Shop or Field Testing

Major replaceable units shall provide, to the extent practical, specific test points for ease of field and shop testing and maintenance. Access to these test points shall be provided utilizing equipment cover plates and/or by unit removal from the equipment rack.

3.5.3 Spares Supply

The spares supplied for the EMS shall be as specified in the contract.

3.5.4 Facilities and Equipments

Maintenance depots shall provide suitable test facilities and equipments to permit fault isolation and corrective maintenance of malfunctioning units, and general equipment servicing. Repairs requiring extensive work or specialized servicing shall be performed by the equipment manufacturer.

Dockside repair shall be possible using no more than a standard volt-ohmmeter and oscilloscope.

3.6 Personnel and Training

The DMS shall be designed to be operated, installed, and maintained by reasonably qualified trained personnel. The vessel captain's operational task shall be minimal, requiring virtually no training except for operational instruction.

3.7 Major Component Characteristics

The characteristics of the major components of the DMS shall be as described below.

3.7.1 Antenna, Unit Designation 101, (UD101)

The antenna shall be a vertical whip marine style antenna approximately 15 foot in length and loaded to operate at Loran A frequency (1900khz).

3.7.2 Loran Receivers, UD 102 and UD 103

The DMS comprises two Loran A receivers, UD 102 and UD 103, each approximately 14" wide x 9" high x 12" deep, such as Nautical Electronics Co., Inc model autofix 500 receiver modified slightly for this application. The performance characteristics of the Loran receivers shall be as follows:

. Sensitivity	1 uv or better
. Signal-to-noise	10 db or better
. Differential Gain	80 db or more
. Spurious rejection	at least 60 db
. Image rejection	at least 80 db
. Bandwidth, 6 db	24 Khz
. Acquisition	Master, manual; slave, automatic hunt and lock
. Track	Automatic
. Loss-of-track-Alarm	BCD signal for automatic indication (loss-of-track condition also shall be readily detectable by manual observation of CRT)
. Receiver Status	BCD signal to printer for continuous recording of receiver status

. LOP output	BCD, 4 wire signal for each of 4 columns to printer for recording of two 4-digit LOP's
. LOP read-out	Displayed on Nixie tubes visible on front panel
. Print Inhibit output	BCD signal to inhibit print command so that recording is not attempted during the interval when the Loran LOP registers are being updated.
. CRT	Visible in daylight without hood, to show position of pedestal gates and Loran envelopes
. PRF	AFC to lock on Loran station prf
. Front Panel Controls	Minimized with appropriate interlocks to ensure proper, simple operation.

3.7.3 Printer Unit (UD 104)

The Printer Unit, UD 104, shall be approximately 9" wide x 6" high x 18" deep, such as Newport Laboratories model 800 modified slightly for this application, or approximately 8" high x 5" high x 16" deep for Monsanto Model 511A modified slightly. This shall be a 21 column printer with alpha-numeric printout (on 3 1/2 inch paper tape) of the data in various columns as indicated below. The printer shall be provided with parallel entry BCD signals where a "0" is from 0V to +0.5VDC and a "1" is from +2.4V to +7.0V DC. The printer shall record data each time it receives a print command. A visible and audible alarm shall be provided to indicate an impending need for replacement of paper.

Column	Function
1 and 2	Vessel identification
3	Event
4 and 5	Spares
6 thru 9	Elapsed time
10	Draft (when used)
11	Loran receiver #2 status
12 thru 15	Loran LOP #2
16	Dump status (if used)
17	Loran receiver #1 status
18 thru 21	Loran LOP #1

3.7.4 Events Unit (UD 105)

The events unit, UD 105, is a custom designed unit approximately 9" wide x 5" high x 10" deep. It shall contain an electronic clock with 4-column BCD output for recording elapsed time. It shall provide a print command to the printer normally every six (6) minutes but every 15 seconds for two minutes following each event. It shall delay a print command to the printer

for the required short interval if it receives a print inhibit signal from the Loran receivers. It shall sound a buzzer and light a flashing panel light if a signal is received indicating loss of automatic Loran lock. It shall transmit a two column pre-set vessel identification BCD signal to the printer. It shall transmit 1-column BCD signals to the printer in response to depression of the following "event" buttons. The "changeable" events buttons 5 through 10 shall be provided to accommodate different vessels, routes, etc., and shall have provisions for the appropriate customized markings.

Button	Event
1	Leaving dock now
2	Starting dump now
3	Completing dump now
4	Return to dock now
5	Passing fix point #1 (e.g., Buoy "XX")
6	Passing fix point #2 (e.g., Ambrose)
7 thru 9	Three additional customized events
10	"Mark Now" (for synchronizing with SIDS)

3.7.5 Equipment Rack (UD 106 or UD 106A)

The equipment rack shall be a custom-designed housing for UD's 103 through 107 inclusive, (all units of the complete DIS except the antenna and Coupler Unit), and shall provide for making the interconnection to ships power and a suitable ground. The equipment rack, UD 106A, approximately 16" wide x 32" high x 20" deep is available as an option for use where less floor or bench space is available in the vessel wheelhouse. The specific Equipment Rack to be delivered shall be as specified in the contract.

3.7.6 Draft Sensing Unit (UD 107)

The Draft Sensing Unit, UD 107, is a custom designed unit approximately 10" wide x 5" high x 17" deep. It shall contain eight adjustable pressure switches, such as Meletron Model 2221-9, and a pressure line for 1/4" IPS connection. The switches normally shall be set to throw at the following fractional parts of full load: 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16, Full. The unit shall withstand a pressure of 65 psi without damage. The contract shall specify the quantity of systems ordered which shall be provided with UD 107.

4. Quality Assurance Provisions

4.1 General

The equipment covered by this specification shall be subjected to those inspections and tests during manufacture which are consistent with the manufacturers normal quality assurance for best commercial practice.

4.2 Acceptance Tests

Acceptance of the DIS shall be at contractor's plant, based upon tests performed by contractor at his facilities and/or subcontractor facilities. The hierarchy of acceptance tests shall be based on unit tests prior to system tests and shall be structured to demonstrate compliance with the significant

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performance requirements of this specification.

4.3 Special Tests

Requirements for special tests, reliability tests, maintainability demonstrations, etc., if any, shall be separately established.

5. Preparation for Delivery

5.1 Packaging

The units of the DMS shall be packaged for delivery in accord with best commercial practice.

5.2 Shipping

Shipping shall be to locations and shall use carriers and routes specified by customer.

Appendix E

Installation Specification

for

Sea Dump Monitoring System

GD-13-1124 (MP)

15 July 1971

[illegible]	SPERRY SYSTEMS MANAGEMENT DIVISION	[illegible] EQUIPMENT SPECIFICATION APPROVAL RECORD

INSTALLATION SPECIFICATION

for

SEA DUMP MONITORING SYSTEM

(DMS)

APPROVALS

NAME	DATE	POSITION
P. Bizzigotti	7/15/71	Research Section Head
J. Charlton	7/15/71	Program Manager

SPECIFICATION [illegible]	[illegible] NO. [illegible]	
GS-13-1124 (HP)		PAGE 1 OF 5

[illegible]

LINE NO.

1. Scope

This Installation Specification establishes the requirements for installation of the Sea Dump Monitoring System (SDMS) aboard vessels to provide surveillance of ocean dumping practices.

2. Reference Specifications

Equipment Specification for Sea Dump Monitoring System, number SB-13-1123(EP), dated 15 July 1971.

Installation Specification for Scow Indicating Draft System, SIDS, number SB-13-1126(EP).

3. Requirements

3.1 System Configuration

The SDMS covered herein is in two forms, [illegible] or [illegible]. The [illegible] comprises 6 units and the [illegible] contains 7 units, as follows and as shown in Figure 1.

UD	Component	Qty/Sys	Approx. Size
101	Antenna	1	15+ ft. whip
102,103	Loran Receiver	2	14"w x 9"h x 12"d
104	Printer Unit	1	9"w x 6"h x 18"d
105	Events Unit	1	9"w x 5"h x 10"d
106	Equipment Rack	1	26"w x 19"h x 20"d
or, option 1 (for use where less floor/bench space is available):			
106A	Equipment Rack	1	16"w x 32"h x 20"d
plus option 2 (used when draft sensing is desired)			
107	Draft Sensing Unit	1	10"w x 5"h x 17"d

3.2 Installed Arrangement, Mounting, and Foundation

All SDMS units except the Antenna are mounted in one rack-and-panel type case, UD106 or UD106A. This Equipment Rack (UD106 or UD106A) shall be located in the vessel wheelhouse. The whip-style antenna, UD101, shall be located externally as high as practicable, at least 15 feet from any [illegible] antenna and at least [illegible] from any vertical ship structure. The routing of the [illegible] shall be kept as short as practicable. The [illegible] also [illegible] UD107 which shall be mounted below [illegible] located to [illegible] and [illegible] to [illegible] existing [illegible]. The [illegible] for mounting shall be as shown in Figures [illegible]. All mounting shall be in accord with best ship practice.

[illegible]

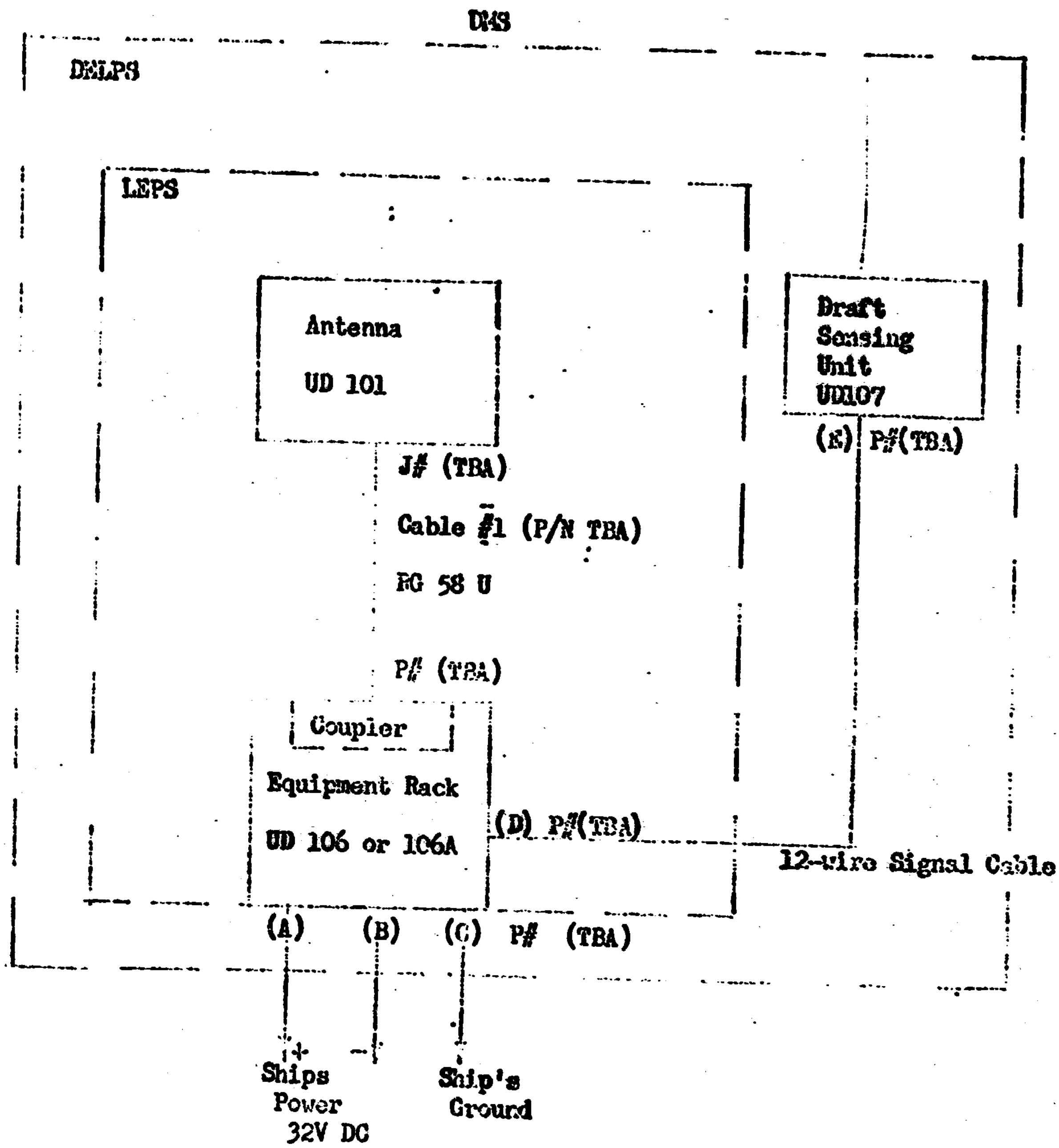

Figure 1 - Installed System Interconnections

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3.3 Electrical Power

The DMS requires a nominal 100 W of electric power at a nominal 32 V DC.

3.4 Electrical Connections

The DMS interconnections shall be as shown in Figure 1. The only external connections to the DMS shall be as shown to Ship's power and ships ground. The wire sizes shall be compatible with the required system drain, nominally 100 watts maximum. The ships power shall be nominally 32 V DC (although 11 V DC to 65 V DC acceptable). RF Cables #1 and #2 shall be made to length, using RG 58 V coaxial cable and ships ground lead shall be at least #12 AWG directly to a suitable rf ground. All wiring shall be in accord with best ship practice.

3.5 Portable Configuration

The NYDCE may provide a portable DMS for temporary use aboard a vessel which only occasionally requires a DMS. The vessel shall be prepared by selecting suitable locations and mountings for the antenna, the coupler unit and the equipment rack; and, by providing suitable ships' power and ground in a plug, P#(TBA), obtained from NYDCE. The antenna unit of the portable DMS is already equipped with universal mounting brackets for temporarily clamping to suitable ships structure. The equipment rack may be lashed down if hard mounting is not practical in the temporary installation. A 30 ft. long r-f antenna cable is provided with the portable DMS.

4. Quality Assurance Provisions

4.1 Inspection

Inspection of the vessel preparation shall be accomplished by vessel owner or his agent and shall be subject to review and approval by NYDCE prior to installation of equipment.

4.2 Checkout

Checkout of the installed equipment shall be accomplished by NYDCE or its designee in the presence of the owner or his agent and shall determine that the installed equipment is functioning properly.

4.3 Operator Training

The system requires very little attention during normal operation (replacement of recorder ribbon and paper, acquisition of Loran master signals, operation of events buttons, etc.). This is normally a responsibility of the

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Captain and is sometimes delegated to the First Mate. Training in these relatively simple procedures will be provided once (to the owner, the Captain, and the Mate) preferrably at the time of equipment checkout.

5. Notes

5.1 Titles to Equipment

The equipment of the DMS shall remain the property of the NY District, U. S. Corps of Engineers. Tampering with the equipment and/or recorded data is not permitted, under penalty of law. Only normal operation and replacement of printer ribbon, paper tape and fuses accessible on the front panel are permitted without express written permission of NYDCE. Each indication or suspicion of system malfunction or need for other maintenance shall be promptly reported (e.g., by radio or telephone) to NYDCE. The NYDCE will be permitted timely access for servicing and removal/replacement of equipment.

5.2 Use of Navigation Information

On the front panel of the Loran receivers are presented the two Loran A current lines-of-position as determined by the DMS. These LOP's may be used as a navigation aid at the discretion of the Captain without obligation on the part of the U. S. Corps of Engineers.

Appendix F

Equipment Specification

for

Scow Indicating Draft System (SIDS)

SPERRY
SYSTEMS MANAGEMENT DIVISION

EQUIPMENT SPECIFICATION
APPROVAL RECORD

EQUIPMENT SPECIFICATION

FOR

SCOW INDICATING DRAFT

SYSTEM (SIDS)

APPROVALS

NAME	DATE	POSITION
P. Bizzigotti	7/15/71	Research Section Head
J. Charlton	7/15/71	Program Manager

SPECIFICATION NUMBER AND DATE: CS-15-1125(BP)

CODE IDENT NO. 14301

SM 3132-2

1. Scope

This specification establishes the performance, design, development and test requirements for a draft sensing subsystem to provide detection of ocean dumping by towed scows, hereinafter called the Scow Indicating Draft System (SIDS).

2. Applicable Documents

The equipment for this system shall be designed and manufactured to best commercial practice and accordingly no MIL specs are involved.

3. Requirements

3.1 System Definition

The SIDS is intended to provide detection and monitoring of ocean dumping by towed dump scows in conjunction with an installed LEPS (Loran-Events Unit-Printer System) aboard the towing tug. The SIDS shall provide measurement of scow draft with equipment to record draft changes for the complete ocean dumping mission. Correlation of the SIDS recorded draft data with the LEPS recorded data is accomplished by the tug Captain using a "mark now" operational procedure prior to and upon return from the dump mission as well as the "Dumping Now" event recorded by the LEPS digital printer compared to an expected change in draft of the scow as recorded by SIDS.

3.1.1 General Description

The SIDS shall incorporate draft sensing and recording equipments to provide the required system function with minimal operational participation by crew and shall be capable of installation and operation on various types of dump scows.

3.1.2 Dump Missions

The SIDS installed on towed scows shall provide monitoring of scow draft for the duration of the dump mission to both near shore and long range dump sites. Mission times corresponding to these dump missions varies but for specification purposes, 10 hour and 40 hour mission times, respectively shall be considered applicable.

3.1.3 Functional Flow Diagram and Interface Signals

The SIDS functional flow diagram and electrical interface signals shall be as specified in Figure 1 and Table 1.

LINE NO.

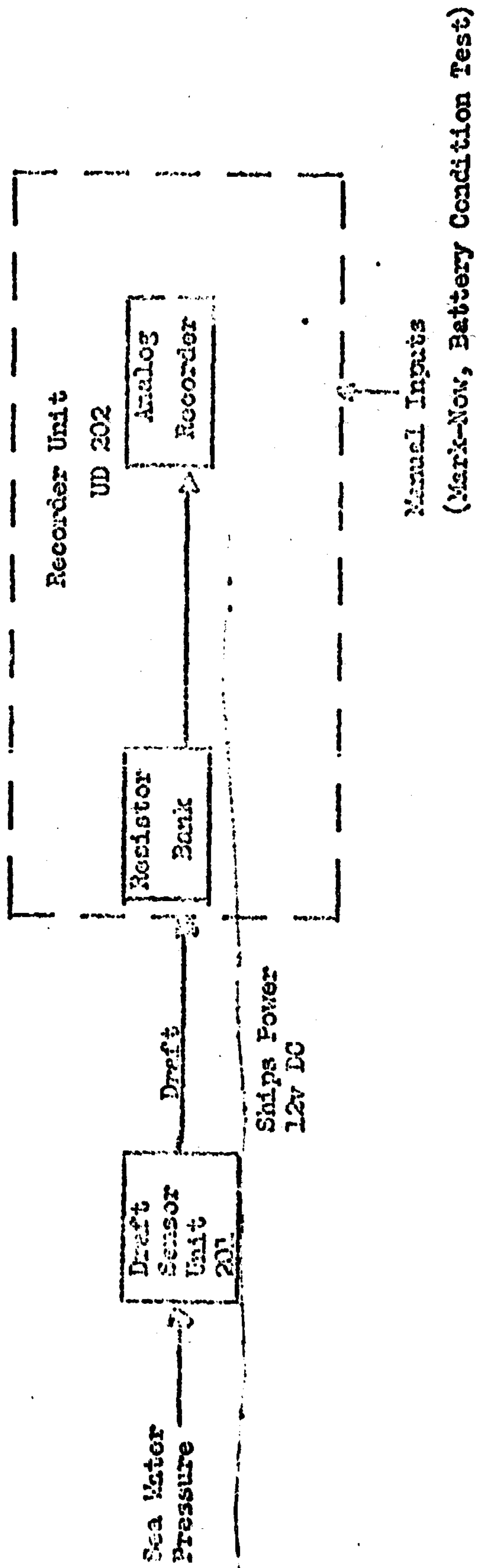

FIGURE 1

STDC FUNCTIONAL FLOW DIAGRAM

From	To	Function	Signal Characteristic
Draft Sensing Unit	Recorder Unit	Scow Draft Change	Changes in scow draft at steps of 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16, Full
Ship's Power	Recorder Unit	Power	Nominally 1.0 watt at 12v DC

TABLE 1 - SIDS ELECTRICAL INTERFACE

3.1.4 Physical Arrangement and Major Components

The major components of SIDS are identified in the following table. The Draft Sensing Unit (UD 201) shall be installed within existing piping on the dump scows and the Recording Unit (UD 202) shall be installed in the scow deck house at a location convenient for the "mark-now" operational procedure and servicing.

UD	Component	Qty/Sys	Approx Size	Description
201	Draft Sensing Unit	1	10"x5"x17"	Custom design comprising pressure switches such as Meletron 2221-9
202	Recorder Unit	1	8"x14"x10"	Custom design comprising Analog Recorder such as Rustrak 288

3.1.5 Detailed Features

3.1.5.1 Operating Modes

The following operational modes shall be provided:

- o Power-Off Mode
- o Operate Mode

3.1.5.1.1 Power-Off Mode

The power-off mode shall be the de-energized status of SIDS and shall be available when system functions are not required or when malfunction, maintenance, or other requirements necessitate withdrawal of power.

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3.1.5.1.2 Operate Mode

The operate mode shall be entered by switch activation of the recording unit. In this mode, continual monitoring of scow draft to and from the dump site shall be provided by an analog recorder. The recording unit shall contain a manually operated momentary holding switch used for the "Mark-Now" operating procedure to provide sufficient time to compensate for the stylus print cycle interval.

3.1.5.2 Electrical Power

The SIDS equipment, normally energized from the scow power source nominally shall require 1.0 watt at 12V DC.

3.1.5.3 Cooling Requirements

The SIDS shall operate without need of external cooling or heating devices for the service conditions specified in paragraph 3.2.6.

3.1.5.4 Data Transmission

The scow draft measurement recording along with the IEPS digital printer tape shall be transmitted to the Corps of Engineers via U.S. mail or Courier within a time period to be specified by the DOE. The operating concept is based on the tug Captain or other person of authority validating the recorded data by a signed statement attesting to the fact that the data was not manipulated and providing additional information to the recorded data such as type of waste, date and hour of leaving and return to dock, and vessel identity.

3.2 Characteristics

3.2.1 Performance Characteristics

The SIDS shall provide recorded measurement of the scow draft in accordance with the following incremental steps of draft relative to full load draft: 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16, and Full.

3.2.1.1 Pressure Switch Accuracy

The pressure switches of the Draft Sensing Unit shall be activated with a pressure repeatability of 2% of the set pressure.

3.2.1.2 Recorder Accuracy

The recorder unit drive motor shall provide a chart speed accuracy of 1% of its normal operating speed. The recording error shall not exceed ± 2% of full scale.

3.2.2 Physical Characteristics

3.2.2.1 Weight and Size

The total weight and size of the SIDS onboard equipment shall be consistent with good design practices for the intended application.

3.2.2.2 Tamperproof

The system equipments shall, to the maximum extent practicable, provide security from unauthorized adjustment and/or tampering.

3.2.2.3 System Installation and Interchangeability

The SIDS shall be designed for easy installation aboard various types of dump scows. The recording unit would be typically located in the scow deck house and the draft sensing unit typically installed on the inboard side of existing sea cocks below the scow waterline. Although such installation may be customized, each unit shall be interchangeable with other similarly marked units without modification. (Adjustment of the pressure switches is permitted.)

3.2.3 Reliability

3.2.3.1 Operational Life

The equipment shall have a minimum total operating life of 5000 hours without major overhaul but including normal servicing and replacement of parts.

3.2.3.2 Operational Stability

The equipment shall satisfy the requirements of this specification continuously or intermittently for a period of at least 400 hours without necessity for any adjustments other than normal operations.

3.2.3.3 Reliability of SIDS Units

The pressure switches on the draft sensing unit shall provide a minimum of 500,000 cycles without failure. The recorder unit operating life shall have an MTBF of 2000 hours.

3.2.4 Maintainability

Maintenance shall be based upon the concept of [illegible] replacement of the Recorder Unit and the Draft Sensing Unit, and replacement of detailed parts and components at the depot or factory, as appropriate. Replacement of Recorder paper [illegible] be [illegible].

3.2.4.1 Equipment Maintainability

The SIIS equipment shall have a Mean Time To Repair (MTTR) of 1 hour excluding logistics/administrative time.

3.2.4.2 Built-In Test Features

The Recorder Unit shall provide a push-to-test battery condition meter to provide a visual indication of the scow battery voltage level, using a depressed zero meter.

3.2.5 Service Ambient Conditions.

The SIIS equipments shall operate satisfactorily under any of the environmental service conditions or reasonable combinations of these conditions as specified in the following table.

Ambient Temperature: 0 to 100°F
Sea State: Beaufort Scale 8 (gale force winds of 40 kts)
Relative Humidity: As normally encountered in a salt-sea atmosphere.

3.3 Design and Construction

The design and construction of the SIIS shall be in accordance with the following subparagraphs.

3.3.1 Materials, Processes, and Parts

In the selection of materials and parts for the SIIS, fulfillment of the major objectives of the system shall be the prime consideration. Emphasis of the environmental and service conditions imposed on the equipments shall be a major consideration in the design and selection of system components. Materials and processes shall be utilized, where appropriate which minimize deterioration and corrosion due to the salt-sea atmosphere.

3.3.1.1 Cabling and Connectors

The SIIS equipments shall use cables and connectors to be specified by the contractor.

3.3.1.2 Standard Parts and Materials

The SIIS equipments shall utilize, where feasible, standard commercial parts and materials. Non-standard parts shall be permitted when equipment performance degradation or system reliability is significantly reduced by using standard parts.

LINE NO.

3.3.2 Nameplates and Product Marking

Nameplates and product marking for equipment identification shall be in accordance with standards to be specified by contractor and will clearly show ownership of equipment by the Corps of Engineers.

3.3.3 Workmanship

Workmanship shall be of high quality to assure fulfillment of the design objectives of the SMS. Military specification MIL-STD-454, requirement 9 shall serve as a guide in the design and procurement of parts and equipment which might largely follow best commercial practice.

3.3.4 Interchangeability

The SMS equipments and component parts shall permit interchangeability with other manufactured or supplied designated equipment and parts unless stipulated differently by model, drawing changes or other information by contract or order. The interchange of units shall not significantly alter system performance or reliability.

3.3.5 Safety

The SMS design shall assure operational safety of the vessel crew and/or maintenance personnel. The electrical system shall provide suitable fusing and grounding of equipments to minimize electrical shock hazards. The equipment shall not exhaust any flammable, explosive, or toxic gas during normal operation or at elevated temperatures up to 250°F ambient.

3.4 Documentation

Documentation requirements, if any, shall be as specified in the contract.

3.5 Logistics

3.5.1 Maintenance Philosophy

The system shall be designed to require minimum maintenance and adjustment over its useful life. Maintenance shall be performed on a unit exchange level at [illegible] and/or equipment manufacturer facilities. Shipboard maintenance at dockside shall be considered only to the extent of replacement of fuses, adjustments, and replacement of separately installable units.

LINE NO.

3.5.2 Shop or Field Testing

Major replaceable units shall provide, to the extent practical, specific test points for ease of field and shop testing and maintenance. Access to these test points shall be provided utilizing equipment cover plates and/or by unit removal from the equipment rack.

3.5.3 Spares Supply

The spares supplied for the SIDS shall be as specified in the contract.

3.5.4 Facilities and Equipments

Maintenance depots shall provide suitable test facilities and equipments to permit fault isolation and corrective maintenance of malfunctioning units, and general equipment servicing. Repairs requiring extensive work or specialized servicing shall be performed by the equipment manufacturer. Dockside repair shall be accomplished using no more than a standard voltohmmeter and oscilloscope.

3.6 Personnel and Training

The SIDS shall be designed to be operated, installed, and maintained by reasonably qualified trained personnel. The vessel Captain operational task is minimal requiring virtually no training except for operational instruction.

3.7 Major Component Characteristics

The characteristics of the major components of the SIDS shall be as described below.

3.7.1 Draft Sensing Unit (UD 201)

The Draft Sensing Unit is comprised of eight adjustable pressure switches mounted in a single housing which, with the Recording Unit series resistor bank provides step changes in circuit resistance when the preset pressure switches make contact. DC voltage to the circuit is provided by the existing scow battery. The pressure switches shall be like Meletron Model no. 2221-9. The overall size of the housing is approximately 10"x5"x17". The draft sensor unit will provide measurement of step changes of vessel draft relative to the full load draft in the following steps: 1/4, 1/2, 5/8, 3/4, 13/16, 7/8, 15/16 and Full. The performance characteristics of the pressure switches shall be as follows:

o Sensor Repeatability at Pressure Set	2% of Range
o Pressure Range	0.75 to 20 psi
o Overtravel	0.2 psi
o Maximum Pressure Without Damage	65 psi

LINE NO.

3.7.2 Recorder Unit (UD 202)

The Recorder Unit contains an analog DC recorder similar to Rustrak Model 288, a resistor bank, and a battery condition meter. The approximate size of the recorder is 5-5/8"h x 3-5/8"w x 4-1/8"d. The overall size of the Recorder Unit is approximately 8" x 14" x 10". The recorder which provides an inkless, dry writing, rectilinear recording shall have the following characteristics:

Selectable Chart Speed	Setable for 1, 2, 3, 4, 6, 10, 12 and 15 inches/hour
Writing Speed	1 stroke per 2 seconds
Chart Speed Accuracy	± 0.5%
Recording Accuracy	± 2% of full scale
Full Scale Range	0 to 30 milliamps
Chart Width	2-5/16"
Chart Roll Length	63 feet

The resistor bank shall contain a setable resistor to adjust the overall current to the recorder, which shall be limited to 30 ma.

4. Quality Assurance Provisions

4.1 General

The equipment covered by this specification shall be subjected to those inspections and tests during manufacture which are consistent with the manufacturers normal quality assurance for best commercial practice.

4.2 Acceptance Tests

Acceptance of the SIDS shall be at contractor's plant, based upon tests performed by contractor at his facilities and/or subcontractor facilities. The hierarchy of acceptance tests shall be based on unit tests prior to system tests and shall be structured to demonstrate compliance with the significant performance requirements of this specification.

4.3 Special Tests

Requirements for special tests, reliability tests, maintainability demonstrations, etc., if any, shall be separately established.

LINE NO.

5. Preparation for Delivery

5.1 Packaging

The units of the SIDS shall be packaged for delivery in accord with best commercial practice.

5.2 Shipping

Shipping shall be to locations and shall use carriers and routes specified by customer.

Appendix G

Installation Specification

for

Scow Indicating Draft System (SIDS)

GP-13-1126(NP)

July 15, 1971

SPERRY RAND	SPERRY SYSTEMS MANAGEMENT DIVISION	EQUIPMENT SPECIFICATION APPROVAL RECORD

INSTALLATION SPECIFICATION

FOR

SCOW INDICATING DRAFT SYSTEM

(SIDS)

APPROVALS

NAME	DATE	POSITION
P. Bizzigotti	7/15/71	Research Section Head
J. Charlton	7/15/71	Program Manager

SPECIFICATION NUMBER AND DATE	CODE IDENT NO. 10304	
GP-13-1126(HP)		PAGE 1 OF 4

1. Scope

This Installation Specification establishes the requirements for installation of the Scow Indicating Draft System (SIDS) aboard towed scows. The SIDS is used in conjunction with the LEPS installed on the towing tug to provide surveillance of ocean dumping.

2. Reference Specifications

- Equipment Specification for Scow Indication Draft System (SIDS), number GP-1125-(NP), dated 15 July 1971.
- Equipment Specification for LEPS and DELPS, number GP-1123(NP), dated 15 July 1971.

3. Requirements

3.1 System Configuration

The SIDS is comprised of the Draft Sensing Unit, UD 201 and the Recording Unit, UD 202 as shown in Figure 1. Approximate size is as follows:

UD	Component	Qty/Sys	Approx. Size
201	Draft Sensing Unit	1	10" x 5" x 17"
202	Recording Unit	1	8" x 14" x 10"

3.2 Installed Arrangement, Mounting and Foundation

The Recording Unit containing the DC analog recorder, battery meter, resistor bank, and "Mark-Now" switch are mounted in one case and shall be installed in the scow deck house in a convenient location for operation and servicing. The Draft Sensing Unit shall be located below decks and installed on existing piping inboard of sea cocks so that it senses sea water pressure. The location shall permit occasional servicing. All mounting shall be in accord with best ship practice.

3.3 Electrical Power

The SIDS, which requires a nominal 1.0 watt at 12v DC, shall be operated from an existing battery source aboard the scow. A battery meter contained in Recorder Unit UD 202 shall be utilized to check battery condition prior to leaving dockside for a dump mission.

LINE NO.

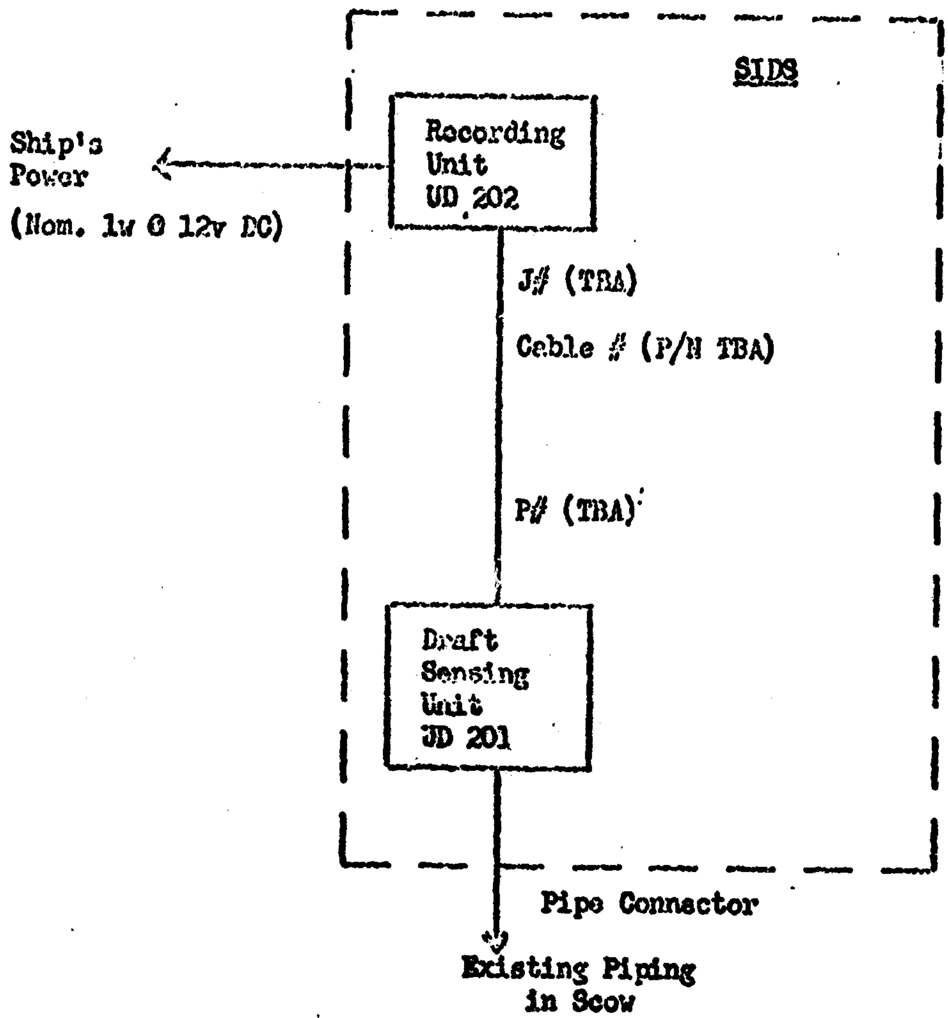

FIGURE 1 INSTALLED SYSTEM INTERCONNECTIONS

LINE NO.

4. Quality Assurance Provisions

4.1 Inspection

Inspection of vessel preparation shall be accomplished by vessel owner or his agent and shall be subject to review and approval by NYDCE prior to installation of equipment.

4.2 Checkout

Checkout of installed equipment shall be accomplished by NYDCE or its designee in the presence of the owner or his agent and shall determine that the installed equipment is functioning properly.

4.3 Operator Training

The system requires very little attention during normal operation (replacement of recorder paper, "Mark-Now" manual switch activation, battery status check, etc.). This is normally the responsibility of the tug vessel Captain and is sometimes delegated to the First Mate. Training in the above operations will be provided at the time of equipment checkout.

5. Notes

5.1 Titles to Equipment

The equipment of the SIDS shall remain the property of the NYDCE. Tampering with the equipment and/or recorded data is not permitted, under penalty of law. Only normal operation and replacement of recorder paper are permitted without express written permission of NYDCE. Each indication or suspicion of system malfunction or need for other maintenance shall be promptly reported (e.g. radio or telephone) to NYDCE. The NYDCE will be permitted timely access for servicing and removal/replacement of faulty equipments.

Appendix H

Principal Investigators

This study was basically performed by the following principal investigators at SSMD:

Mr. Pio Bizzigotti	Research Section Head
Mr. John Charlton	Program Manager

Consultation and contributions were made by the following SSMD personnel in the specific areas indicated:

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Mr. M. Hans	Ocean Instrumentation
Mr. R. Hedelson	Loran
Mr. J. Morrison	Loran, Omega
Mr. A. Sperber	Radar, Beacons
Mr. R. Wochinger	General, Printers, Draft Sensing
Capt. L. Kapanka	Ship Operation

APPENDIX I

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